

Jan. 11, 1938.

A. N. GOLDSMITH

2,105,318

SYNTHETIC REVERBERATION SYSTEM

Filed Dec. 6, 1935

4 Sheets-Sheet 1

Fig. 1

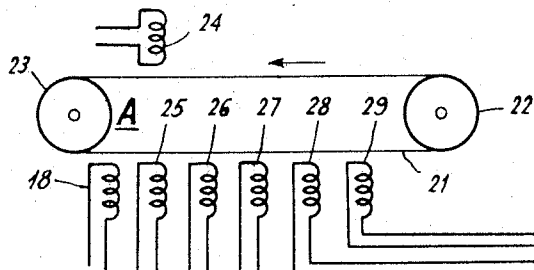
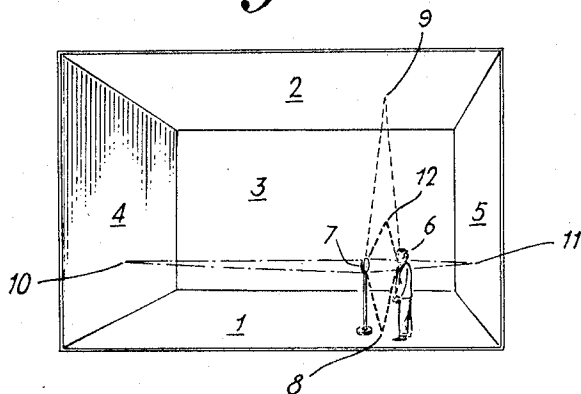
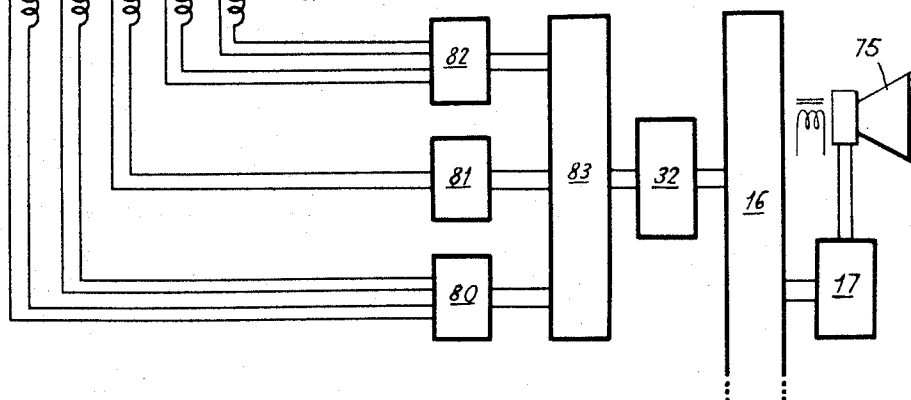


Fig. 3



INVENTOR
ALFRED N. GOLDSMITH

BY

H. S. Brown

ATTORNEY

Jan. 11, 1938.

A. N. GOLDSMITH

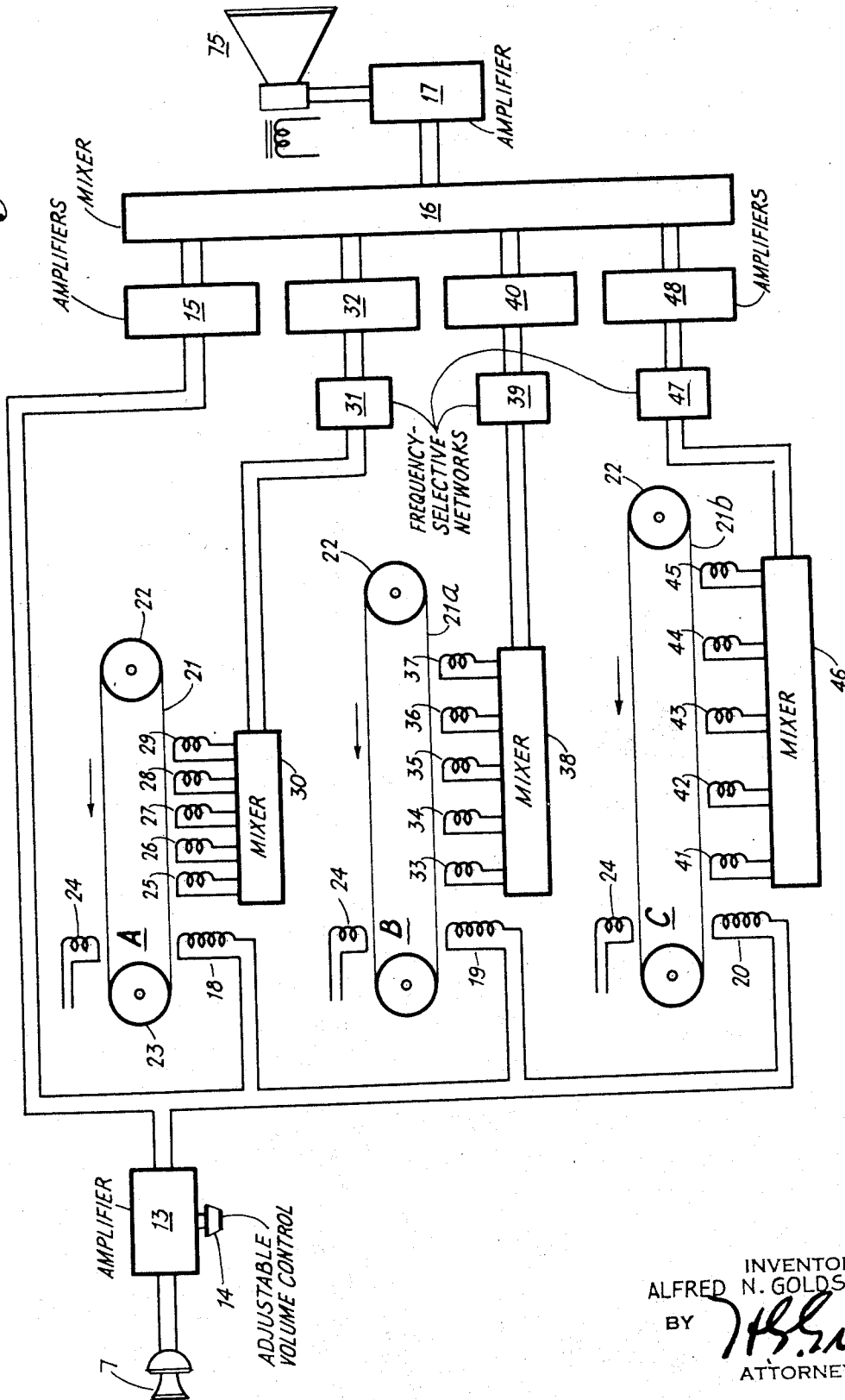
2,105,318

SYNTHETIC REVERBERATION SYSTEM

Filed Dec. 6, 1935

4 Sheets-Sheet 2

Fig. 2



INVENTOR
ALFRED N. GOLDSMITH
BY *H. H. Hovee*
ATTORNEY

Jan. 11, 1938.

A. N. GOLDSMITH

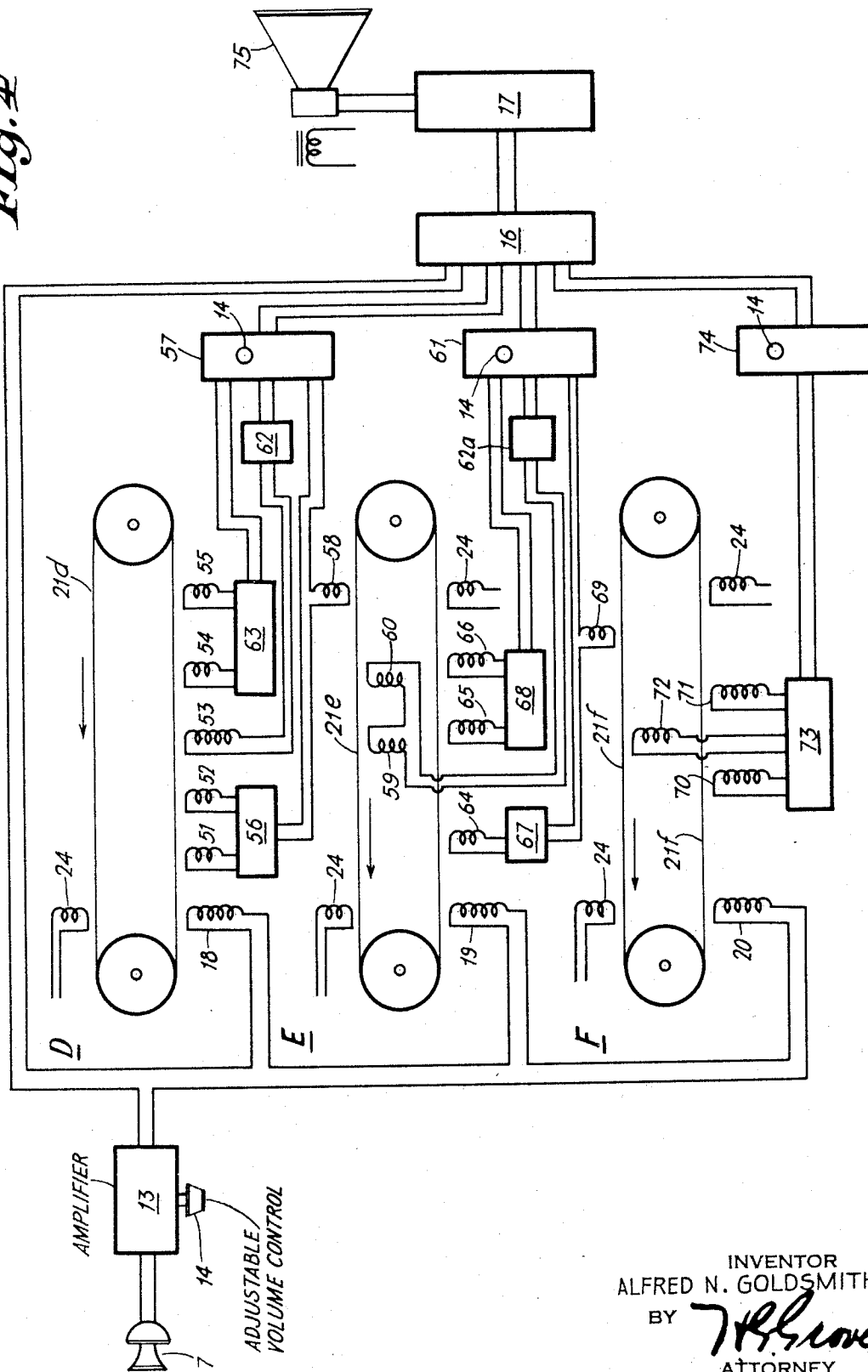
2,105,318

SYNTHETIC REVERBERATION SYSTEM

Filed Dec. 6, 1935

4 Sheets-Sheet 3

Fig. 4



INVENTOR
ALFRED N. GOLDSMITH

BY

7 H. H. H. H. H.
ATTORNEY

Jan. 11, 1938.

A. N. GOLDSMITH

2,105,318

SYNTHETIC REVERBERATION SYSTEM

Filed Dec. 6, 1935

4 Sheets-Sheet 4

Fig. 7

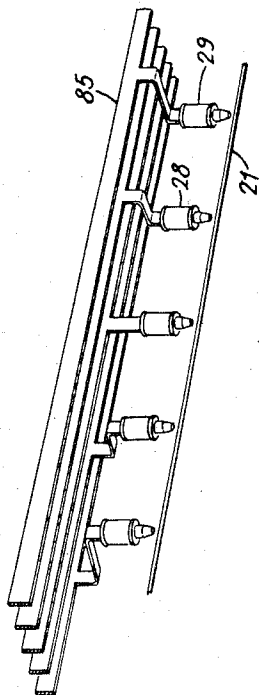


Fig. 6

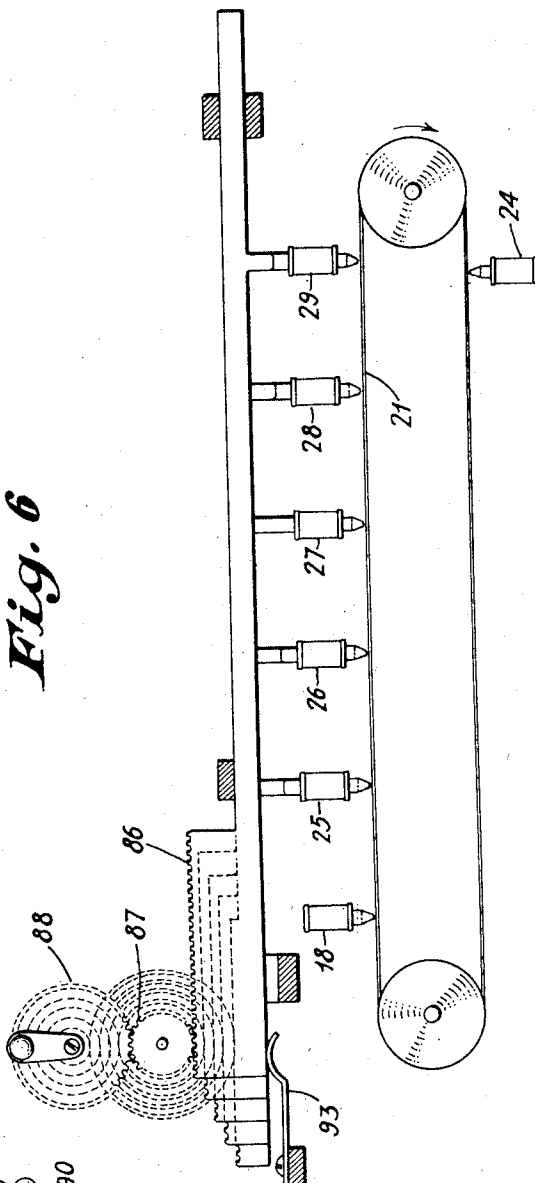
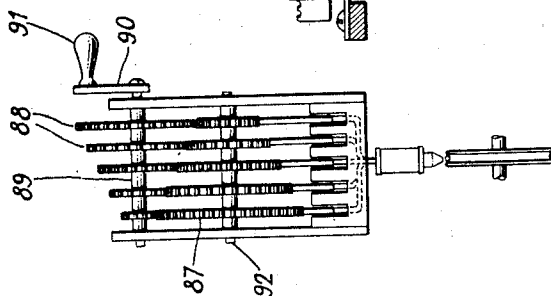


Fig. 5



INVENTOR
ALFRED N. GOLDSMITH

BY

H. H. Brown
ATTORNEY

UNITED STATES PATENT OFFICE

2,105,318

SYNTHETIC REVERBERATION SYSTEM

Alfred N. Goldsmith, New York, N. Y.

Application December 6, 1935, Serial No. 53,159

13 Claims. (Cl. 179-100.2)

This invention relates to a system for producing synthetic reverberation, and has more particularly to do with electrical apparatus and methods of employment thereof in which the natural accompaniment of sound broadcasting or sound recording in an auditorium having desirable reverberation characteristics may be artificially simulated when the same sound is produced in a small chamber or one which is acoustically "dead"; that is to say, non-reverberant.

One of the major problems of sound broadcasting, sound recording, and sound reproduction is the control of the amount and type of reverberation in the recording or pick-up part of the system and also in the reproducing part of the system.

When the pick-up for broadcasting or recording is obtained in a small and acoustically dead room, particularly for a musical program, the result oftentimes lacks the richness, fullness and corresponding emotional appeal that is to be desired. It is unfavorably regarded alike by skilled musicians and the lay public.

On the other hand, music recorded in a large reverberant room, studio, or auditorium has a rounded and spacious quality which is far more pleasant. The effect in question is noticeable even with small orchestras (that is, string trios or quartets) and becomes extraordinarily significant in the case of large brass bands and symphony or theater orchestras. Needless to say, satisfactory quality in music, properly rendered according to these criteria, is directly translatable into box office receipts in the theater, or audience attention and advertiser satisfaction in the case of broadcasting.

Unfortunately the use of adequately large studios of the correct reverberation characteristics is both inconvenient and uneconomic, for the following reasons. Large rooms are expensive to build and to insulate acoustically from their possibly noisy surroundings (as is generally the case in cities). The acoustic characteristics of a large room are alterable only to a limited extent, with difficulty, and at considerable cost. A rapid and controllable change in the acoustics of a large room is generally not feasible, and yet such a change is called for when a sudden transition between loud music and soft speech is needed, taking a typical example.

It has been determined empirically by engineers experienced in the broadcasting art that a certain studio volume is best adapted for a given number of musicians or other artists producing a given

program. The findings of these engineers are set forth in the following table:

Number of artists	Approximate best studio volume (cu. ft.)	Best studio height	Dimensions (in feet)	
			Width	Length
4	4,000	10	15	25
12	10,000	14	21	35
30	23,000	18	28	48
100	79,000	28	41	69

It will be noted that the considerable studio height required, particularly in the two last cases given in the table, leads to costly or impracticable constructions.

It is among the objects of my invention:

1. To provide apparatus for adding to the rendition of a program a controllable amount of room reverberation, corresponding to a selected size of room and a chosen wall material.
2. To provide a sound pick-up system suitable for use in small and inexpensive studios, while securing the effect of far larger and more costly studios.
3. To provide apparatus for use in connection with sound recording or reproducing equipment whereby the acoustics of a theater (having a loud speaker amplifying installation) may be simulated by the addition to the original recording of a desired and controllable reverberant effect.
4. To provide a recording system comprising means for the introduction of reverberation corresponding to recording in a room of any desired shape and wall material into a record.
5. To enable reverberation to be modified electrically so as to simulate the effects corresponding to a moving source of sound in a reverberant space.
6. To provide a simple form of equipment and one which is readily handled with one, two or rarely more adjustments corresponding respectively to the apparent room dimensions, the acoustic effects of which are to be simulated for the addition of a desirable amount and kind of reverberation to the non-reverberant record where the original pick-up was obtained in a room inadequately supplied with reverberant characteristics.

In carrying out my invention I preferably employ electrical circuits and synthetic methods for the production of reverberation effects corresponding to those naturally obtained in a room of any size. In an acoustically dead room brief impulses will be heard or recorded followed in-

stantly by practically complete silence. Suppose, however, a replica of the impulse, but of lesser amplitude or intensity, is produced by a suitable means and that this replica is sounded (that is, 5 produced in the air of the room or on a record) after a suitable brief delay corresponding to the time of passage of the impulse sound to an imaginary reflecting wall and back to the ear of the auditor. The effect of a single echo and a slight amount of reverberation is thus obtained. 10 Assume the same process to be continued by the addition of a number of suitably time-spaced replicas of the original impulse, the replicas having controlled and suitably diminishing amplitudes or intensities. The auditor will then get the impression that the original impulse occurred in a large reverberant room, the walls of which reflected all sound frequencies equally. If, however, the successive impulse-replicas are modified 20 in wave form (for example, by passage of the thereto corresponding currents through appropriate electrical networks), it is possible to simulate reverberation in a room having walls of the corresponding selective-frequency reflecting characteristics, and thus add to the naturalness of the "synthetic reverberation". The details of the procedure described in general terms above will further appear in the following descriptions and from the illustrative figures.

30 The processes in question can be applied to simulate the acoustics and reverberation in small auditoriums, in theaters of any size, and even in such complicated structures as domed building interiors. A study of the multiple reflection of a sharp impulse in such structures, following by determination of the frequency-selection of the wall materials in reflecting sound will yield the necessary data for setting the reverberation synthesizer.

40 While it is essential to the carrying out of my invention that scientific data should be available for correlating the acoustic conditions of an auditorium with the various settings of the pick-ups on the telegraphone wire to be used in the 45 process of obtaining reverberation effects, it may be helpful to understand that adjustments can be made in the apparatus itself under the guidance of the satisfactory quality of the results produced when varying the controls one way and 50 another. It will be borne in mind that in any auditorium, acoustic delays are largely attributable to the three major room dimensions and to the velocity of sound waves reflected from the four walls, the floor, and the ceiling. The effect 55 in the various tonal frequencies of reflection from the wall surfaces can readily be simulated in the corresponding electrical wave filters of my apparatus according to conventional and well known theory. The energy losses with successive reflections of the sound waves in an auditorium 60 may also be simulated by experimentally setting the volume controls for the different replica channels in my apparatus so as to produce a satisfactory blending of the original sound wave with 65 the delayed replica waves.

It is reasonable to extend the preceding procedure from an impulsive sound to a sound of any type. Thus it becomes possible to make a master record, for example, in an acoustically 70 "dead" room and, from this master record, by re-recording electrically with the accompanying family of controlled reverberations, to produce records which seem to correspond to sound recorded in a room of larger dimensions and with 75 moderate reverberation, or alternatively in a room

of great dimensions and marked reverberation. From such a group of records it is possible to select one most appropriate for reproduction in a room of specific acoustic characteristics. For example, the record containing maximum reverberation might well be suitable for reproduction in the home or a small theater (that is, in rooms having limited reverberation). It is possible to conceive, in other words, of a commercial procedure wherein "graded records" are sold, the 10 purchaser (with some assistance, perhaps) selecting the record most appropriate for use under the conditions in which it will be played.

In producing such a family of "graded records", or indeed in producing a record having any 15 desired amount and type of reverberation, it is clear that the method of adjusting the reverberation synthesizer may be on the basis of general acoustic theory applied to a room of the desired characteristics; or it may be on the basis of experiments made in such rooms and the duplication of the results obtained therein; or it may be on a purely empirical and experimental basis. The method selected is without effect on the validity and scope of this invention. 25

It is possible also to modify reverberation, for example in the recording of a sound motion picture, so as to simulate the effects of motion of the source of the recorded sound. Suppose, as a simple example, that a speaker is shown passing from a 30 small anteroom into a large audience chamber. By changing the reverberation to higher values and with more marked reflection for the lower frequencies as the speaker is seen to pass into the large chamber, the effect of the motion will 35 be realistically simulated acoustically.

In the particular forms of reverberation synthesizer described in detail below, the telegraphophone has been shown as a relatively simple, inexpensive, and conveniently adjustable form of 40 delay device for the production of the successive controlled replicas of the original sound which, in their totality and in combination with the original sound, will produce the desired effect. Any other of the known forms of acoustic or electric delay devices may be employed (for example, 45 disc or cylinder recorders with multiple reproducer pick-ups, acoustic transmission lines, or electric delay circuits) without affecting the scope of the invention. The selection of the appropriate multiple delay device will generally be determined by economic considerations, compactness, and ease of manipulation.

It may be mentioned that, while it is preferable that the multiple delay device used in the 55 reverberation synthesizer should be one which produces no undesired acoustic distortion of any type (frequency distortion, harmonic distortion), yet the requirements in this respect are not so rigorous as for a normal precision recorder because 60

(a) the successive reverberation replicas have a lower amplitude than the original sound, and a greater error in recording can accordingly be tolerated.

(b) the successive reverberation replicas will 65 have a deliberately introduced distortion corresponding to the selective reflection from the walls of the apparent recording room, and the deliberately introduced distortion can be adjusted with 70 due account of and reference to that occurring in the multiple-delay device. The nature of these procedures will become clearer after consideration of the actual form of the reverberation synthesizer.

(c) in any case, the reflective quality (that is, the selective reflection) of the walls is vaguely defined by most people, and therefore some errors in the successive reverberation replicas will not result too seriously so far as their conjoint effect is concerned.

It is among the advantages to be derived from carrying out my invention, that it is possible to give the performing artist in a "dead" studio some idea of how the reproduction of his voice will sound in a large auditorium. This is accomplished by placing near him a directional loud speaker pointed at him. The loud speaker is so arranged that the directional pick-up microphone does not pick up any substantial portion of the speaker output, the methods of so doing being well known. The loud speaker in question is connected into a portion of the output of the reverberation synthesizer circuit. Thus the artist hears himself apparently in a reverberant room, although he is actually recorded or picked-up in a "dead" room. If desired, the artist may use ear-phones instead of a loud speaker.

The details of my invention and the mode of operation thereof will best be understood upon reference to the following description when read in connection with the accompanying drawings in which

Figure 1 shows in perspective a room in which is a microphone and an artist whose voice is to be broadcast or recorded;

Fig. 2 shows diagrammatically and conventionally certain elements of electrical circuits and apparatus which may be used for the synthetic production of reverberation effects to be added to the original pick-up of a sound program;

Figs. 3 and 4 show respectively modified circuit diagrams representing embodiments of my invention alternative to that of Fig. 2; and

Figs. 5, 6 and 7 show a system for adjusting the reverberation characteristics of my synthesizer for the purpose of simulating the effects that would be obtained in rooms of different size.

Referring first to Fig. 1, I show the outlines of a studio room having a floor 1, a ceiling 2, a back wall 3 and side walls 4 and 5. The perspective is taken from a point of view such that nothing would be visible in the studio unless the front wall were made transparent. Within the studio I show an artist 6 who is presumed to be giving a performance before a microphone 7. The sound of his voice travels directly to the microphone over a path 6, 7. The sound of his voice also travels to the floor, the ceiling and the four walls, and is reflected back at points such as 8, 9, 10, 11 and 12 respectively and thence into the microphone 7. The distance travelled by the sound waves in each case depends upon the positions of the artist and of the microphone with respect to the reflecting points on the floor, the ceiling and the walls. The summation of the various sounds thus received by the microphone leads to the reverberation effect in question. It should be understood that the description herein given is purposely over-simplified, since it neglects a number of reflections of higher orders, reflections resulting from certain oblique paths, the effect of the selective reflection of the various surfaces (on the quality of the individual reflected sounds), and the effect of oblique incidence of the reflected sounds on the (generally directional) microphone. However, it is suitable for the establishment of the principle that reverberation can be simulated by adding to the original sound a number of suitably time-delayed,

amplitude-controlled, and frequency-characteristic-modified replicas of the original sound; and that the closeness of the approximation to actual reverberation in a given room will depend on the number of such artificially produced replicas and their resemblance to the actual individual reverberations. For the purposes of this analysis and the explanation of my invention, this principle is adequate.

Fig. 2 shows conventionally a circuit diagram for a reverberation synthesizer according to a preferred embodiment of my invention. Here the microphone 7 is shown connected to an amplifier 13 having incorporated therein a volume control device 14. The output circuit from the amplifier 13 feeds energy to a second amplifier 15 and thence to a mixer 16. Output energy from the mixer may then be impressed upon a further amplifier 17 and thence to a utilization circuit which may include any sound reproducing device 18 or sound recorder. Included also in the output circuit from the amplifier 13 is a plurality of coils, such as 18, 19 and 20 for controlling a registration of the original sounds upon a telegraphophone apparatus or a plurality of the same. For illustrative purposes I have shown three telegraphophones A, B and C. It is well known that if a tempered steel wire is passed at a constant velocity past the poles of an electromagnet it may be variably magnetized so as to retain the effects of sound waves variably impressed upon different portions of its length. Such a wire I have shown at 21 carried by a driving pulley 22 and an idler pulley 23. Similar wires 21_a and 21_b constitute elements of the other telegraphophones B and C respectively. These telegraphophones are controlled by the magnetizing coils 19 and 20 respectively. Means (not shown) are provided for driving the pulleys 22 at a constant speed. The number of telegraphophones to be used in any case may be more or less than three depending upon the refinements of reverberation effects to be obtained. My invention is best illustrated, however, by the use of three telegraphophones merely because they correspond in their effects to the reverberation producing characteristics of the ceiling and floor, the near side walls, and the remote side walls respectively. Each telegraphophone is provided with an erasing coil 24 supplied with direct current for wiping out the magnetization effects of previous recordings before again being used.

When the reverberation synthesizer, as shown in Fig. 2, is in use, it is to be presumed that the microphone 7 has been placed in a room having relatively dead reverberation characteristics and that reverberation effects are to be introduced into the sound reproduction in controlled amounts and mixed with the amplified output coming directly from the microphone. Hence I utilize a portion of the current in the output circuit from the amplifier 13 for actuating the magnetic coils 18, 19 and 20 so as to store the sound records in the three respective telegraphophones. The records so stored are then utilized by reaction upon a series of coils in which the original sound records are regenerated with different amounts of delay corresponding to the time intervals which elapse between the passing of a given portion of the wire 21 past the coil 18 and past successive pick-up coils 25, 26, 27, 28 and 29. Each of the coils 25 to 29 inclusive is connected with a mixer device 30, the output from which may be impressed upon a frequency selective network 31. Device 31 has an output

circuit which feeds energy to an amplifier 32 and thence to the general mixer 16. Similarly the telegraphone B comprises the wire 21^a, a recording coil 19, and a plurality of pick-up coils 33, 34, 35, 36 and 37. These last mentioned coils are connected to another mixer 38 which feeds its energy to a frequency selective network 39 and thence through an amplifier 40 to the general mixer 16. The same arrangement may again be used in connection with the telegraphone C which has a recording wire 21^b, a recording coil 20, and pick-up coils 41, 42, 43, 44 and 45 connected with a mixer device 46. The output circuit of the latter feeds energy to a frequency selective network 47 and thence through an amplifier 48 to the mixer 16.

The functions of the various coils which are connected to the mixers 30, 38 and 46 may be explained as follows: The shortest reflected sound path between the points of origin of the sound itself and the microphone 7 is that which includes the point of reflection 8 on the floor of the studio. Coil 25 is, therefore, used to simulate the delay effect of the sound reflected from the floor. Coil 26 represents the delay effect of the reflection from the ceiling point 9. When the sound travels over a path such as to include two reflections, as, for example, from the floor to the ceiling and thence to the microphone, or from the ceiling to the floor and thence to the microphone, the delay incident to its arrival at the microphone may be represented by the position of the coil 27. Furthermore, because there are two such paths having substantially equal length, the number of convolutions in the winding 27 may be twice as great as those in either of the coils 25 and 26, thus doubling the amplitude of this particular replica. The coils 28 and 29 may be further provided for simulating the delay action of sound waves reflected back and forth between the floor and the ceiling three and four times. The frequency selectors 31, 39 and 47 may be designed according to well-known theory for simulating the frequency absorptive properties of reflecting surfaces in the walls, floor and ceiling of an auditorium.

The telegraphones A, B and C are structurally similar, though they may be differently dimensioned. The function of each telegraphone is to supply certain reverberation effects which are lacking in the wave train originally picked up by the microphone 7, but which are desired for enhancing the quality of reception of a given program, and for simulating the echo effects in an auditorium of suitable size. Thus, if telegraphone A is used to simulate the sound wave reflections from the floor and ceiling, then telegraphone B may be caused to provide simulations of the sound wave reflections from the front and back walls, while telegraphone C provides the simulation of sound wave reflections from the side walls 4 and 5.

The several telegraphones A, B and C may be mechanically interconnected and driven from a common motor, if desired. Furthermore the phonic wires 21, 21^a, 21^b may all be driven at the same velocity, or at different velocities, according to preference. In either case the spacings between the recording coil 18 and each of the pick-up coils of the group 25 to 29 inclusive are made as nearly as possible proportional to the distances that would be traversed by reflected sound waves in an auditorium having the microphone a given height above the floor and a ceiling a given height above the microphone. Likewise

the spacings of the coils 33—37 away from the recording coil 19 will preferably be made proportional to the distances that would be traversed by reflected sound waves in the same auditorium and from the source of sound to the reflecting points of the two nearer walls and thence to the microphone. The same disposition of the coils 41—45 with respect to the recording coil 20 is to be had on the telegraphone C, that is to say, proportionately spaced with respect to the distances that would be traversed by reflected sound waves from the source of the sound to the reflecting points on the further walls and thence to the microphone.

In Fig. 2 the output energies from the respective mixers 30, 38 and 46 are separately filtered through respective frequency selective networks 31, 39 and 47. These energies are then further amplified by passing them through the amplifier devices 32, 40 and 48 whence they are applied to the mixer 16 where all energies including the directly propagated electrical equivalents of the sound waves and the synthesized reverberation effects are combined, further amplified in the device 17 and then applied to a utilization device such as the loud speaker 75.

Referring to Fig. 3, I show a modification of my invention in which the reverberation effects due to single, double, and higher order reflections are separately treated in order to obtain different frequency response characteristics. According to this arrangement it may be possible to more exactly simulate the wall effects in successive reflections of various orders. The coils 25 and 26 are set to pick up the single reflections. These are applied to a frequency selective circuit 80. The double reflections are picked up on coil 27 and applied to the frequency selective network 81. The triple and quadruple reflections are respectively picked up on the coils 28 and 29 and given a similar treatment when passed through the frequency selective network 82.

The output energies from the frequency selective networks are combined in the mixer 83, amplified by the network 32, combined in the device 16 with energies corresponding to reflections from other walls as produced by different telegraphones B and C (the same as shown in Fig. 2), further amplified in the device 17 and utilized in the reproducer 75.

Still further improvements and refinements in the process of synthesizing the reverberation effects may be obtained according to the modification of my invention shown in Fig. 4. According to the system therein shown it may be possible to provide a manifold utilization of each frequency selective network. This is done by introducing stages of frequency selection intermediate between two or more delay operations. Since the circuits shown in Fig. 4 are quite different from those shown in Fig. 2 or in Fig. 3 the reference characters applied in Fig. 4 are not entirely the same as in the other figures. The recording coil 18 on telegraphone D serves to impress the original sound record upon the phonic wire 21^d and this sound record is picked up at five points thereby introducing different delays according to the spacings of the coils 51, 52, 53, 54 and 55 away from coil 18. Coils 51 and 52 represent first reflections and are therefore treated by a frequency selective network 56, the output energy from which is not only impressed upon the mixer device 57 but has also in circuit therewith a recording coil 58 which cooperates with the

telegraphone E. The telegraphone E is preferably arranged to have two erasing coils 24 where simultaneously two records may be made on different portions of the wire 21a. The recording as provided by the coil 58 is again picked up on the coils 59 and 60 and applied to the frequency-selective filter 62a and thence to the mixer device 61. Since coils 51 and 52 gave two reflections from say the floor and ceiling respectively, the echo effects will be doubled on the upper part of the recording wire 21a and these echo effects will be quadrupled and picked up at different points as by the coils 59 and 60.

The pick-up coil 53 on telegraphone D is in circuit with its own frequency-selective network 62. The reflections of higher orders as picked up on the coils 54 and 55 may be applied to a frequency-selective network 63. All of these energies are then applied to the mixer 57 and thence to the general mixer 16 and amplifier 17.

The telegraphone E is also provided with a recording coil 19 in association with pick-up coils 64, 65 and 66. Coil 64 has its own frequency-selective network 67 while coils 65 and 66 have a frequency-selective network 68 common thereto. The same process of introducing further delays into the output energy from the selective network 67 may be had by applying a portion of this energy to a recording coil 69 which is in association with the recording wire 21r of the telegraphone F. Another portion of the energy from the frequency-selective network 67 is also applied to the mixer 61. The telegraphone F also functions to introduce certain delays in the pick-up of energy as recorded on the bottom portion of the recording wire 21r at the coil 20. The pick-up from the two simultaneous but different recordings on two portions of the telegraphone F is obtained by coils 70, 71 and 72, all of which connect with a frequency-selective network 73. The output energy from the network 73 may then be applied to the amplifier 74 and thence to the general mixer 16, the amplifier 17 and the utilization device 75, which may be either a reproducer or a recorder of any suitable type. If a recorder is used, it may be of the disk type, or a wax cylinder, or a film.

It will be understood that Fig. 4 is merely representative of a wide variety of combinations of frequency-selective networks with arrangements for delaying the sound effects so as to simulate different echoes from auditoriums of different size and having different frequency absorption characteristics of the wall materials for giving the reflection of sound waves of certain frequency spectra. This figure of the drawings also suggests to those skilled in the art other possibilities for economizing on the number of frequency selective networks to be used, since a single such network may serve the manifold purposes of characterizing a plurality of simulated echo effects.

When the delayed replica trains of sound impulses are combined with the original train through the mixer device 16, the relative amplitudes of each train or each group of trains can be controlled by means of separate volume control devices 14, as shown in Fig. 4. Such volume control devices may be used anywhere in the different stages of amplification, as is well known, and it is merely in the interest of simplicity of the disclosure that they have not been represented more generally in the drawings, particularly in Figs. 2 and 3. It will be understood, therefore, that in order to simulate the natural reverberation effects to which one is accustomed, the re-

production of the original wave train will be the loudest, and replica trains of the first, second and higher orders will preferably be reproduced with gradually diminishing intensity.

Another consideration which deserves mention at this point is the correct phasing of the circuits for the replica wave trains in relation to each other and in relation to the original wave train. Obviously if, in the synthesizing process, the electrical wave generated in any of the pick-up coils is not fed to the mixer device in proper phase, then the circuit connections may easily be reversed.

In Figs. 5, 6 and 7 I show schematically a suggested mechanical arrangement for quickly adjusting the positions of the entire multiplicity of pick-up coils to be used with the different telegraphones so as to simulate in rapid succession the reverberation effects characteristic of rooms of different size. The mechanism has been illustrated only with respect to one of the telegraphones but it can readily be seen that the moving parts can all of them be geared together for controlling the pick-up coils which are associated with the entire group of telegraphones.

For convenience in illustrating the structure I have shown the pick-up coils 25, 26, 27, 28 and 29 as cooperating with the upper stretch of wire 21, instead of the lower stretch thereof, as shown in Fig. 2. However, there are no limitations to be imposed upon the carrying out of my invention as regards which portion of the telegraphone is to be used.

In the practically designed telegraphone, as is well-known in the art, the recording coils and pick-up coils are provided with pole pieces preferably adapted to at least partially surround the steel wire on which the record is to be made. The constructional features of these pole pieces are not within the scope of my invention and for this reason I have not attempted to illustrate them in the drawings exactly as they would appear when designed for efficient operation. Instead, I have merely shown the coils 18 and 25 to 29 inclusive in Figs. 6 and 7 as having tapered ends closely adjacent the recording wire 21. It will be understood, therefore, that any preferred arrangement of the pole pieces in cooperation with the recording wire may be used.

Each of the coils 25 to 29 inclusive is preferably supported by a slide rod 85, at one end of which is provided a rack 86 adapted to mesh with a gear such as 87. The gear 87 also meshes with another gear 88 mounted on a shaft 89 at the end of which is a crank 90 having a control handle 91. The shaft 89 carries a plurality of gears 88, each having a different diameter. The gears 87 vary in diameter inversely as the diameters of the gears 88 with which they mesh. The gears 87 are loosely mounted on the shaft 92, whereas the gears 88 are fixedly mounted on the shaft 89.

In accordance with the arrangement shown in Figs. 5, 6 and 7 it will readily be seen that the coils 25 to 29 inclusive may be variably spaced from one to the next simply by turning the crank handle 91. For a given angle of rotation of the shaft 89 the different slide rods 85 are given progressively increasing longitudinal movements depending upon the gear ratios of the respective pairs of gears 87 and 88.

If the reverberation effects of a small room are to be simulated, it is, of course, to be understood that the coils 25 to 29 inclusive must be positioned relatively near each other, whereas if the rever-

beration effects of a large auditorium are to be simulated, then the spacing between the coils must be increased. The mechanism shown provides this possibility of adjustment at a moment's notice at any time during the rendition of a program.

One of the advantages of the arrangement shown in Figs. 5, 6 and 7 is that if it is desired to simulate the acoustical conditions which would prevail when a performer enters the stage after having already commenced his program "back-stage", then at the moment when he makes his entrance upon the stage the reflecting properties of a room with greater dimensions can be instantly simulated by rotating the crank 81 so as to extend the delay action of the different replica trains.

In order to provide for the possibility of simulating echo effects in rooms of different relative dimensions it may be desirable to vary the meshing of the racks 86 with their respective gears 87 so that at any one adjustment certain ones of the coils 25 to 29 inclusive will be closer together than certain ones of the adjacent coils. In order to effect this adjustment it is merely necessary to disengage any of the racks 86 from their cooperating gears 87 by depressing them against the resilient springs 93. When so depressed the rack 86 may be shifted longitudinally into another position of engagement with its gear 87, and then afterwards released. The relative spacings between the coils will then be maintained for any adjustment of the crank 80.

It should be further understood that the scope of this invention is wide, and includes for example, the following instances:

Use of a reverberation synthesizer between a pick-up microphone in a broadcasting studio and the control room amplifier.

Use between a pick-up microphone in broadcasting a remote control event and the wire line to the transmitting station or a central control point.

Use between the pick-up microphone in sound recording and the control room amplifier, at the time of recording.

Use between a film phonograph, in the process of film re-recording, and the re-recorder.

Use between a recorded film in a film phonograph, in theater reproduction of the film, and the loud speaker amplifiers or the loud speakers.

Use between the pick-up and amplifier of a disc electric phonograph and the loud speakers.

Otherwise stated, the reverberation synthesizer may be used at practically any point in a sound recording, pick-up, or reproducing system of electrical nature, the selection of the exact point of insertion in the system being a matter of economics and convenient engineering design and handling.

To those skilled in the art many modifications of my invention will suggest themselves in view of the foregoing description. My invention, therefore, is to be given all that breadth of protection which the scope of the appended claims will permit.

I claim:

1. In a synthetic reverberation producing system, means for translating a train of directly propagated sound waves into a train of electrical waves, electrical means for storing the effects of the train of electrical waves, means under control of the stored effects for producing at least two unequally delayed replicas of the original train of electrical waves, means for accurately

adjusting the time constant by which each replica train is delayed, thereby to simulate natural reverberation effects, means including a mixer circuit for obtaining a composite wave train the components of which include the original train and the replica trains, and means for so controlling the amplitudes of the respective replica trains that they are caused to simulate successive echo effects in an auditorium.

2. A system in accordance with claim 1 in which the last said means is adapted to independently control the amplitude of each component of the composite wave train.

3. A system in accordance with claim 1 and having a plurality of primary mixer circuits for respectively different groups of replica trains, a secondary mixer circuit, and independent frequency selective means interposed in the respective paths from each primary mixer circuit to said secondary mixer circuit.

4. In a synthetic reverberation producing system, a pick-up device responsive to directly propagated sound waves, an electrical wave translating network under control of said pick-up device, a plurality of wave train recorders in circuit with said network, means under control of each recorder for storing and reproducing with independently adjustable delay characteristics facsimile wave trains, means for variably adjusting the amplitude of each facsimile wave train, and mixer means whereby a portion of the output energy from said pick-up device is combined with a controlled amount of energy from each unit of the facsimile wave train reproducing means.

5. In a synthetic reverberation producing system, means for immediately translating a relatively non-reverberant train of directly propagated sound waves into a train of electrical waves, electro-mechanical means for storing the effects of the original train of electrical waves, a plurality of pick-up devices operable concurrently with the storing means for initiating further trains of electrical waves which simulate echo effects of the original wave train, means for combining the waves of the original train with the different echo-simulating trains, and means for controlling the phase relations between the waves of the different trains.

6. A synthetic reverberation producing system comprising a microphone operable in surroundings which are deficient in reverberant qualities, means under control of said microphone for electrically transcribing electrical wave trains corresponding to a sound wave train introduced into said microphone, means for producing a plurality of delayed replica wave trains from the effects of said transcribing means, frequency-selective means for modifying certain of said replica trains, and means for combining the replica trains with the electrical wave train which is originated at said microphone.

7. In a system for the transmission and reproduction of sound effects, a sound pick-up device, means under control of the sound pick-up device for generating a plurality of echo effects, means including gear mechanism having predetermined relative movements of different elements thereof for adjusting the last said means so as to simulate echoes in a chamber of any desired dimensions, means for combining the resultant echo effects with the original sound effects, and means for reproducing the additive combination of sound effects.

8. A synthetic reverberation producing system

comprising, a microphone, an electrical transmission system connected to said microphone, recording apparatus operable under control of an original wave train generated in said transmission system, means for producing a plurality of delayed electrical wave trains corresponding to and immediately following the original wave train, means for combining the delayed wave trains in controlled amplitudes with the original wave train and means including a manually controlled gear mechanism for varying the time of delay of the different trains.

9. A sound wave synthesizer for use in connection with a source of sound comprising means for converting sound waves into electrical waves, means operable contemporaneously with the first said means for repeating the electrical waves a plurality of times, each time with a different delay constant, independent means for variably controlling different delay constants so as to simulate echo effects in auditoriums of different sizes, and means for combining in controlled amplitudes the repeated waves and the original wave.

10. A synthetic reverberation producing system comprising a source of electrical waves corresponding to a train of relatively non-reverberant sound waves, means for recording the electrical waves, means for repeating the electrical waves a plurality of times contemporaneously with the recording thereof, each time with a delay constant corresponding to a desired echo effect, means for combining the original waves with the repeated waves, means for controlling the phase relationships between the original and the repeated waves, and means for utilizing the resultant of the combined waves by way of simulating the sound effects that would obtain if said source of electrical waves had originally included reverberation effects.

11. A synthetic reverberation producing system comprising a source of electrical waves corresponding to a train of relatively non-reverberant sound waves, means for recording the electrical waves, means for repeating the electrical waves

a plurality of times contemporaneously with the recording thereof, each time with a delay constant corresponding to a desired echo effect, means including a plurality of frequency selective filters through different ones of which certain of the repeated waves are respectively passed for modifying the tone qualities thereof, means for combining the original waves with the repeated waves, and means for utilizing the resultant of the combined waves by way of simulating the sound effects that would obtain if said source of electrical waves had originally included reverberation effects.

12. A synthetic reverberation producing system comprising a source of electrical waves corresponding to a train of relatively non-reverberant sound waves, means for recording the electrical waves, means for repeating the electrical waves a plurality of times contemporaneously with the recording thereof, each time with a delay constant corresponding to a desired echo effect, means for separately controlling the amplitude of each wave, means for combining the original waves with the repeated waves, and means for utilizing the resultant of the combined waves by way of simulating the sound effects that would obtain if said source of electrical waves had originally included reverberation effects.

13. A synthetic reverberation producing system comprising a source of electrical waves corresponding to a train of relatively non-reverberant sound waves, means for recording the electrical waves, means for repeating the electrical waves a plurality of times contemporaneously with the recording thereof, each time with a delay constant corresponding to a desired echo effect, means for adjusting the delay constants to simulate echo effects in auditoriums of different size at different times, means for combining the original waves with the repeated waves, and means for utilizing the resultant of the combined waves by way of simulating the sound effects that would obtain if said source of electrical waves had originally included reverberation effects.

ALFRED N. GOLDSMITH.