Feb. 3, 1959 P. C. GOLDMARK 2,872,515

SYNTHETIC REVERBERATION SYSTEM

Filed Sept. 2, 1954 3 Sheets-Sheet 1

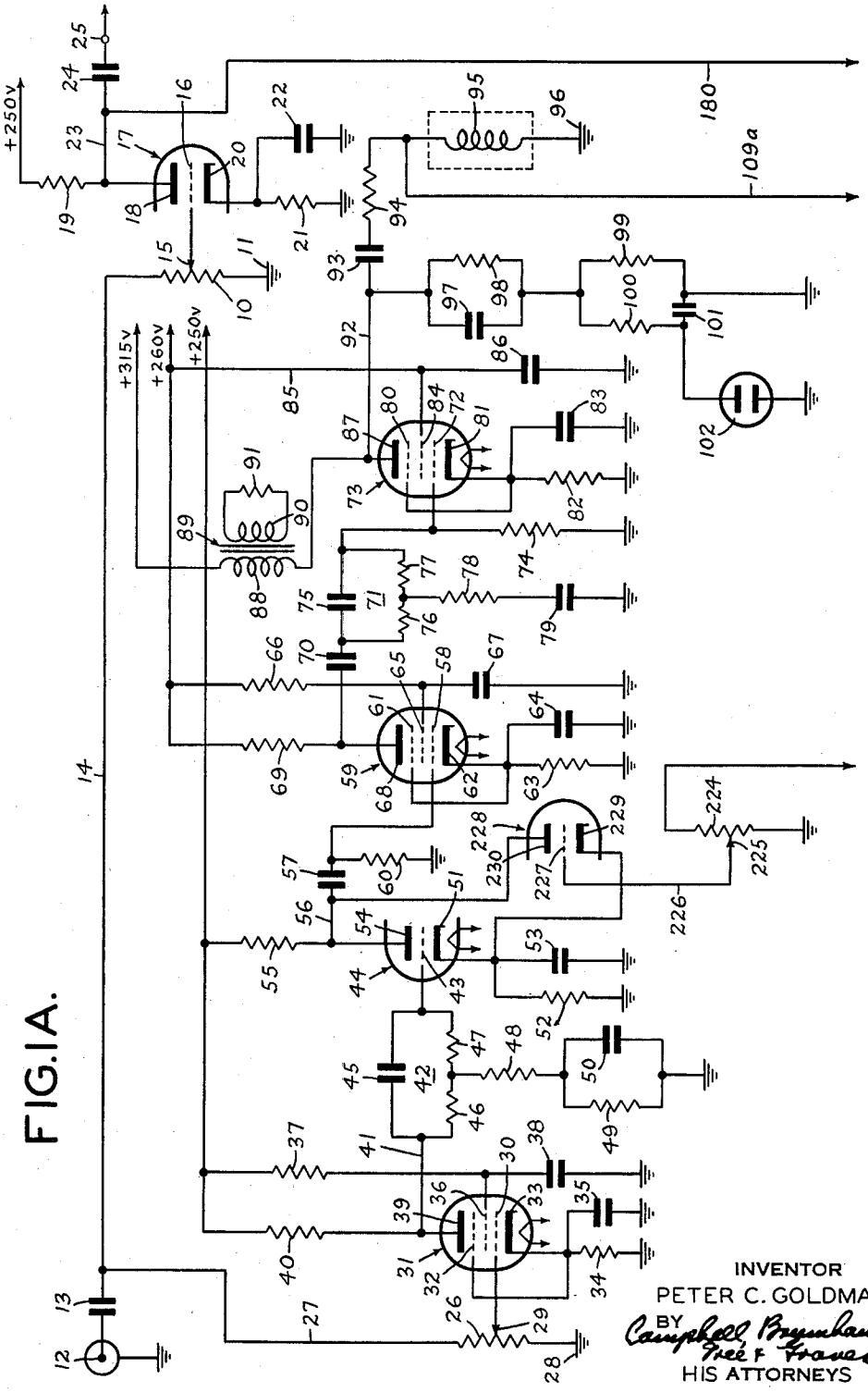


FIG.1A.

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3 Sheets-Sheet 2

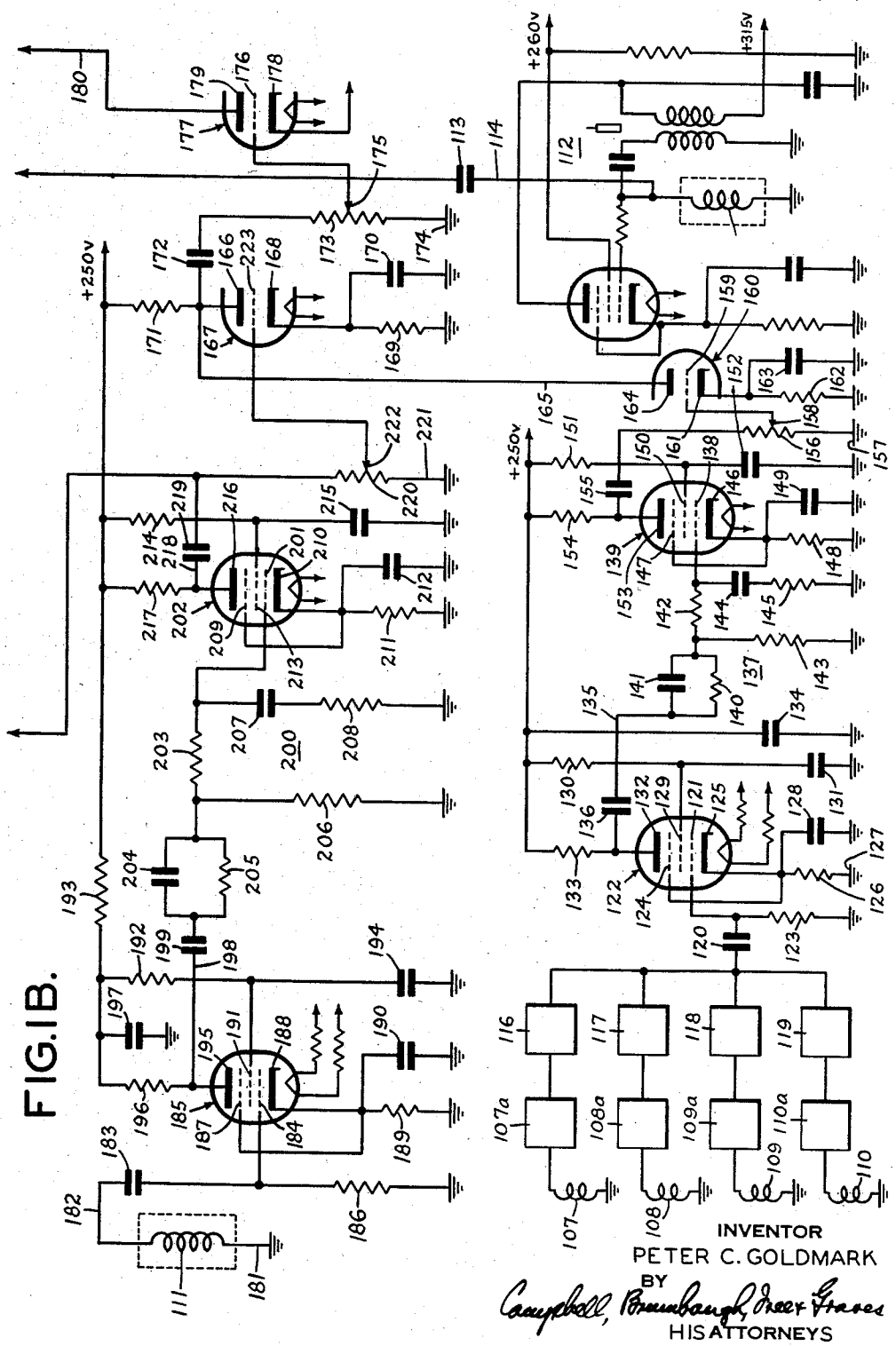


FIG. 1B.

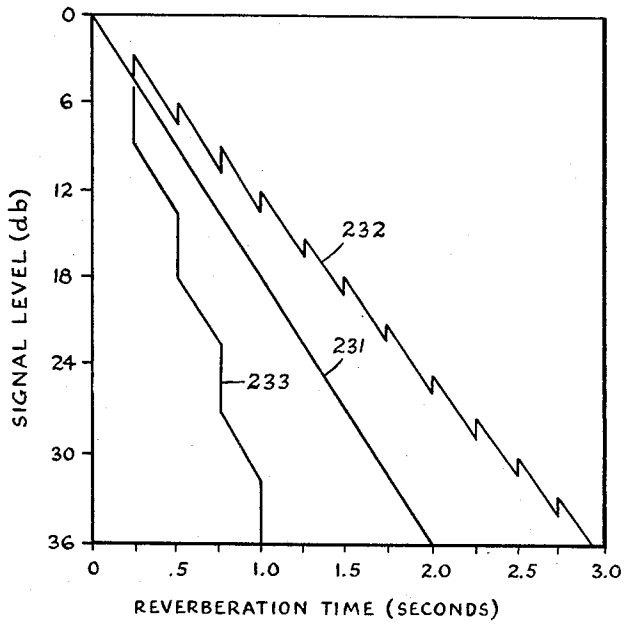
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SYNTHETIC REVERBERATION SYSTEM

Filed Sept. 2, 1954 3 Sheets-Sheet 3

FIG.3.



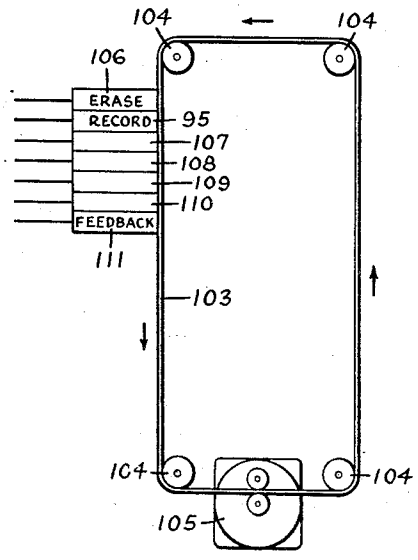


FIG.2.

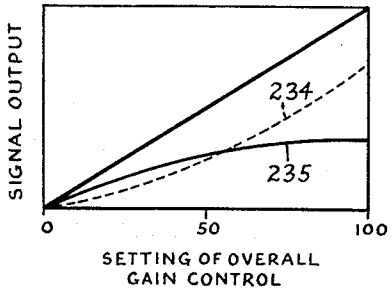


FIG.4.

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2,872,515

SYNTHETIC REVERBERATION SYSTEM

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Application September 2, 1954, Serial No. 453,847

8 Claims. (Cl. 179—1)

The present invention relates to artificial reverberation and more particularly to novel and improved means for generating and combining with an electric signal representing sound energy, other electric signal components of such character as to produce a composite signal representing a direct sound wave and a plurality of reverberation components.

Several different types of synthetic reverberation apparatus have been devised heretofore. In one form, a plurality of acoustic delay lines are used to provide delayed sound waves that are combined with an original sound wave to form a composite signal having reverberation components. While a system of this character can be effective, it tends to be unwieldy and cumbersome because of the considerable lengths of the acoustic delay lines that are needed. It has also been proposed to derive synthetic reverberation signals by recording an original signal on a magnetic tape, for example, and picking up induced signals at spaced apart locations along the tape, which signals are subsequently combined with the original signal to form a composite signal approximating one including reverberation components. Such systems also have not proved entirely satisfactory since the reverberation time could be adjusted only by relatively cumbersome means for mechanically adjusting the spacings between the pickup heads.

It is an object of the invention, accordingly, to provide new and improved synthetic reverberation apparatus that is free from the above-noted deficiencies of the prior act.

Another object of the invention is to provide new and improved synthetic reverberation apparatus that is small in size yet enables a relatively wide range of reverberation times to be attained with simple and readily adjustable means.

Still another object of the invention is to provide new and improved synthetic reverberation apparatus which embodies means for automatically adjusting the amount of reverberation signal according to the volume level so that proper balance between the original signal and the reverberation component is maintained over the operating volume level range.

In its broader aspects, the invention contemplates the recording on an endless record strip such as a magnetic tape, for example, of an electric signal representing an original sound wave. The recorded signal is used to induce in each of a plurality of spaced apart pickup devices a plurality of electric signals, the amplitudes of which are adjusted so that they correspond to points on a mean reverberation curve for the system. A portion of the signal induced in one of the pickup devices is fed back to the device for recording signals on the tape and means is provided enabling adjustment of the amplitude of the feed-back signal to be made such that a number of different reverberation characteristics can be established having total reverberation times between predetermined maximum and minimum values.

According to another feature of the invention, the proportion of reverberation signal to direct signal is varied inversely with the overall volume level so as to compensate for the fact that the reverberation is less noticeable as the listening level is lowered.

For a better understanding of the invention, reference is made to the following detailed description of a typical embodiment, taken in conjunction with the accompanying drawings, in which:

Figs. 1A and 1B when placed side by side form a schematic diagram of synthetic reverberation apparatus constructed according to the invention;

Fig. 2 illustrates schematically an endless record strip together with recording means and pickup means which are used to provide synthetic reverberation signals in the system shown in Fig. 1;

Fig. 3 is a graph illustrating typical reverberation characteristics obtainable with the apparatus of Fig. 1; and

Fig. 4 is a graph illustrating desired characteristics for the relative amounts of reverberation and direct signal at different overall volume levels.

As shown in Fig. 1A, the synthetic reverberation apparatus according to the invention comprises a direct path adapted to receive an electric signal from a suitable source such as a radio receiver or phonograph pickup, for example, and to provide an output signal to a utilization device such as an amplifier or a loudspeaker, for example, together with a reverberation path, responsive to the input signal, for providing a reverberation signal component to be combined with the direct signal.

More specifically, the direct path includes a voltage divider **10**, one terminal of which is connected to ground at **11**, and the other terminal of which is adapted to receive an input signal from a coaxial cable **12** through a condenser **13** and a conductor **14**. The voltage divider **10** has an adjustable contact **15** connected to the control grid **16** of a conventional triode **17**, which may be one-half of a type 6SN7 GT tube, for example, having an anode **18** connected through a load resistor **19** to the positive terminal of a 250 volt source (not shown). The cathode **20** of the triode **17** is connected through a cathode bias resistor **21** to ground and is shunted by the usual by-pass condenser **22**, as shown. The output signal is taken off at the anode **18** of the triode **17** and is fed through a conductor **23** and a D. C. blocking capacitor **24** to an output terminal **25**.

The reverberation path includes a voltage divider **26** which has one terminal connected by the conductor **27** to the conductor **14** in the direct signal path and has another terminal connected to ground at **28**. The adjustable contact **29** of the voltage divider **26** is connected to the control grid **30** of a conventional pentode tube **31**, which may be a type 6AU6 tube, for example, in a conventional preamplifier circuit. Thus, the suppressor grid **32** is connected to the cathode **33** and the latter is connected through the usual cathode bias resistor **34** to ground, the resistor **34** being by-passed by a condenser **35**, as shown. The screen grid **36** is connected through a voltage dropping resistor **37** to the positive terminal of a 250 volt source, a filter condenser **38** being connected between the screen grid **36** and ground. The anode **39** is also connected through a load resistor **40** to the positive terminal of the 250 volt source.

The output of the pentode **31** is taken off at the anode **39** and is fed through a conductor **41** and a filter network **42** to the grid **43** of a conventional triode **44** which may be one-half of a type 6SN7 GT tube, for example. The filter **42** may comprise a series branch including a condenser **45** in parallel with the series connected resistors **46** and **47**, and a shunt branch connected between the midpoint of the resistors **46** and **47** and ground and comprising a series resistor **48** in series with the parallel combination of a resistor **49** and a condenser **50**, as shown.

The triode 44 is connected as a conventional voltage amplifier and its cathode 51 is connected through the usual cathode bias resistor 52 to ground, in shunt with a by-pass condenser 53. The anode 54 of the triode 44 is connected through a load resistor 55 to the positive terminal of the 250 volt source and the output is supplied through a conductor 56 and a condenser 57 to the control grid 58 of a pentode 59, which may be a type 6SJ7 tube, for example, also connected as a voltage amplifier, a grid resistor 60 being connected between the grid 58 and ground. The suppressor grid 61 is connected to the cathode 62 and through the usual cathode bias resistor 63 to ground, the resistor 63 being shunted by the usual by-pass condenser 64. The screen grid 65 is connected through a voltage dropping resistor 66 to the positive terminal of a 260 volt source, and is by-passed to ground by a filter condenser 67. The anode 68 is connected through a load resistor 69 to the positive terminal of the 260 volt source.

The output of the pentode 59 is taken off at the plate 68 and fed through a condenser 70 and a filter network 71 to the control grid 72 of a pentode 73, which may be a type 6V6 GT tube, for example, a grid resistor 74 being connected between the control grid 72 and ground, as shown. The filter network 71 may comprise a series branch including a condenser 75 in parallel with the series connected resistors 76 and 77 and a parallel branch including a resistor 78 and the condenser 79 connected between the midpoint of the resistors 76 and 77 and ground, as shown.

The filter networks 42 and 71 are designed in a conventional manner to compensate for the loss due to the characteristics of the recording and playback processes in magnetic tape recording, caused by the recording and pickup heads, and the magnetic tape, by providing a rise in high frequency response.

The suppressor grid 80 of the pentode 73 is connected to the cathode 81 and through a cathode bias resistor 82 to ground, the resistor 82 being shunted to ground by a by-pass condenser 83. The screen grid 84 is connected by a conductor 85 to the positive terminal of the 260 volt supply and is also by-passed to ground through a condenser 86. The anode 87 is connected to the positive terminal of a 315 volt source through a load impedance including the primary winding 88 of a transformer 89 having a secondary winding 90 connected to a load resistor 91 of relatively low value.

The output from the anode 87 of the pentode 73 is fed through a conductor 92, a condenser 93 and a resistor 94 to one terminal of a conventional magnetic tape recording device 95, the other terminal of which is connected to ground at 96, as shown. Connected between the conductor 92 and ground is a shunt compensating circuit comprising two parallel connected branches in series, one branch including a condenser 97 and a resistor 98, and the other branch including a resistor 99 in one arm and a resistor 100 and condenser 101 in the other arm, a volume level indicator such as a conventional neon tube 102 being connected in shunt with the condenser 101.

As shown in Fig. 2, the recording device 95 is mounted in fixed recording relation to an endless magnetic tape 103 carried by idler rollers 104 and adapted to be driven at constant speed by a motor 105 in the direction indicated by the arrows. Also mounted in operative relation to the endless magnetic tape 103 are a conventional erasing head 106, a plurality of pickup heads 107, 108, 109 and 110, and a feedback head 111.

The erasing head 106 is adapted continuously to erase any information recorded magnetically on the tape 103 immediately prior to the recording of further information by the recording head 95. To this end, the erasing head 106 is connected in the grid circuit of a conventional oscillator 112 (Fig. 1B) which is adapted to generate an alternating electric signal of say 25 kc. per second frequency. The oscillator 112 also supplies a 25 kc. biasing signal to the recording head 95 through the condenser 113 and the conductor 114, in accordance with conventional practice.

The pickup heads 107, 108, 109 and 110 are connected to adjustable attenuators 107*a*, 108*a*, 109*a* and 110*a*, respectively (Fig. 1B), the outputs of which are fed through 25 kc. rejection filters 116—119, respectively, and a condenser 120 to the control grid 121 of a pentode 122, which may be a type 5879 tube, for example, connected in a conventional preamplifier circuit. Thus, a grid resistor 123 is connected between the grid 121 and ground; the suppressor grid 124 is connected to the cathode 125 and through a cathode bias resistor 126 to ground at 127, the resistor 126 being by-passed by a condenser 128; the screen grid 129 is connected through a voltage dropping resistor 130 to the positive terminal of a 250 volt source and is by-passed to ground through a condenser 131; and the anode 132 is connected through a load resistor 133 to the positive terminal of the 250 volt source, a large filter capacitor 134 being connected between the latter and ground, as shown.

The output of the pentode 122 is fed from the anode 132 thereof through the conductor 135, a condenser 136 and a filter network 137 to the control grid 138 of a pentode 139 which may be a type 6SJ7 tube, for example. The filter network 137 comprises a series branch including a resistor 140 and a condenser 141 in parallel, in series with a resistor 142, and a pair of shunt branches, one comprising the resistor 143, and the other comprising a condenser 144 and the resistor 145.

The cathode 146 of the pentode 139 is connected to the suppressor grid 147 and through a cathode bias resistor 148 to ground, the resistor 148 being by-passed by a condenser 149. The screen grid 150 is connected through a voltage dropping resistor 151 to the positive terminal of a 250 volt source and is by-passed to ground through a condenser 152. The anode 153 is connected through a load resistor 154 to the positive terminal of the 250 volt source and through a condenser 155 to one terminal of a voltage divider 156, the other terminal of which is grounded at 157. The adjustable contact 158 of the voltage divider 156 is connected to the control grid 159 of a triode 160, which may be one-half of a 6SN7 GT type tube, for example, the cathode 161 of which is connected to ground through a cathode biasing resistor 162 by-passed by a condenser 163.

The anode 164 of the triode 160 is connected through a conductor 165 to the anode 166 of a triode 167, which may be the other half of the 6SN7 GT type tube, for example, to which part of the output of a feedback circuit to be described hereinafter is applied, so that the outputs of the two tubes are combined. The cathode 168 of the tridoe 167 is connected through a cathode biasing resistor 169 to ground, the resistor 169 being by-passed by condenser 170 in the usual manner. The anode 166 of the triode 167 is connected through a load resistor 171 to the positive terminal of a 250 volt source and through a condenser 172 to one terminal of a voltage divider 173, the other terminal of which is grounded at 174.

The adjustable contact 175 of the voltage divider 173 is connected to the control grid 176 of a triode 177, which may be one-half of the 6SN7 GT tube comprising the triode 17 (Fig. 1A), for example. The cathode 178 is connected in parallel with the cathode 20 of the triode 17 and the anode 179 is connected by a conductor 180 to the anode 18 of the triode 17 so that the output of the triode 177 is combined with the output of the triode 17 to provide a composite signal to the output terminal 25.

The feedback head 111 (Figs. 1B and 2) has one terminal connected to ground at 181 and another terminal connected through a conductor 182 and a condenser 183 to the control grid 184 of a pentode 185, which may

be a type 5879 tube, for example, a grid resistor **186** being connected between the grid **184** and ground, as shown. The suppressor grid **187** of the pentode **185** is connected to the cathode **188** and through a cathode bias resistor **189** to ground, the resistor **189** being by-passed by condenser **190**. The screen grid **191** is connected through voltage dropping resistors **192** and **193** to the positive terminal of a 250 volt source and is by-passed to ground by a condenser **194**. The plate **195** is connected through a plate load resistor **196** and the resistor **193** to the positive terminal of the 250 volt source, a relatively large filter condenser **197** being connected between the junction of the resistors **196** and **193** and ground, as shown.

The output of the pentode **185** is fed from the anode **195** thereof through a conductor **198**, a condenser **199** and a filter network **200** to the control grid **201** of a pentode **202** which may be a type 6SJ7 tube, for example. The filter network **200** comprises a series branch including a resistor **203** in series with a parallel connected condenser **204** and resistor **205** and two shunt paths, one including a resistor **206** and the other comprising a condenser **207** and the resistor **208** in series.

The filter networks **137** and **200** are designed in a conventional manner to compensate for the loss due to the characteristics of the recording and playback processes in magnetic tape recording by providing a rise in low frequency response.

The pentode **202** is connected as a conventional voltage amplifier. Thus, the suppressor grid **209** is connected to the cathode **210** and through a cathode biasing resistor **211** to ground, the resistor **211** being shunted by a by-pass condenser **212**. The screen grid **213** is connected through a voltage dropping resistor **214** to the positive terminal of the 250 volt source and is by-passed to ground through a condenser **215**. The anode **216** of the pentode **202** is connected through a load resistor **217** to the positive terminal of the 250 volt source.

The output of the pentode **202** is connected through a conductor **218** and a condenser **219** to one terminal of a voltage divider **220**, the other terminal of which is grounded at **221**. The adjustable contact **222** of the voltage divider **220** is connected to the control grid **223** of the triode **167**, the plate **166** of which is connected in parallel with the plate **164** of the triode **160**, as described above.

Connected in parallel with the voltage divider **220** is a second voltage divider **224** (Fig. 1A), the adjustable contact **225** of which is connected by a conductor **226** to the control grid **227** of a triode **228**, which may be the other half of the type 6SN7 GT tube comprising the triode **44**, for example, the cathode **229** and plate **230** of which are connected in parallel with the cathode **51** and plate **54**, respectively, of the triode **44**. This portion of the circuit serves to combine a portion of the output of the feedback coil **111** with the direct signal from the conductor **27** for recording by the recording head **95**.

In typical synthetic reverberation apparatus, according to the invention, the magnetic tape **103** (Fig. 2) may be driven by a motor **105** at a speed of say 7½ inches per second. For this speed, the spacings between the recording head **95**, the pickup heads **107**, **108**, **109**, **110** and the feedback head **111** are adjusted to correspond to a mean reverberation characteristic such as that illustrated by the curve **231** in Fig. 3 which represents a reverberation time of two seconds (i. e., the time required for the reverberation component to die down to −36 db). For such a characteristic, the spacings between the recording head **95** and the first pickup head **107** and between the pickup heads **107**, **108**, **109**, **110** and **111** should be made about one-third of an inch. Also the attenuators **107***a*, **108***a*, **109***a* and **110***a* should be adjusted so that the amplitude of the signal passed to the pentode **122** from each of the pickup heads **108**, **109**, and **110** is approximately 1 db lower than the amplitude of the signal from the preceding pickup head.

If no feedback was utililzed in the system, the signals picked up by the five pickup heads **107**, **108**, **109**, **110** and **111** under the conditions described above, would give five points on the curve **231** spaced .044 second apart beginning at the origin. However, by feeding back to the recording head **95** the signal picked up by the feedback head **111**, it is possible to secure a much greater number of points on the curve **231** so that the reverberation sounds much more natural to the listener than would otherwise be the case. For example, if the feedback voltage divider **224** (Fig. 1) is adjusted to feed back to the recording head **95** a signal of such amplitude that the corresponding signal picked up by the pickup head **107** is approximately 1 db lower than the corresponding signal picked up by the feedback head **111**, then the total reverberation signal available at the conductor **180** for combination with the direct signal will include a multiplicity of reverberation components corresponding to the characteristic **231** in Fig. 3.

If, on the other hand, the feedback voltage divider **224** is adjusted to feed back to the recording head **95** a signal of such amplitude that the corresponding signal picked up by the pickup head **107** is substantially greater than 1 db, then a stepped form of curve will be obtained like that represented by the characteristic **232** in Fig. 3. It will be seen that the characteristic **232** approximates a reverberation characteristic of three seconds reverberation time.

In order to obtain a reverberation time characteristic less than 2 seconds, it is only necessary to adjust the feedback voltage divider **224** so that it feeds back to the recording head **95** a signal such that the corresponding signal induced in the first pickup coil **107** is less than 1 db. This will produce a stepped form of characteristic of which the curve **233** is typical, having a reverberation time less than two seconds. By appropriate adjustment of the circuit, reverberation time characteristics over the range from 1.0 to 3 seconds for example, may be readily obtained.

In operation, the voltage divider **26** (Fig. 1A) is adjusted to supply a signal of suitable level to the first pentode **31** and the voltage dividers **173** (Fig. 1B) and **10** (Fig. 1A) are adjusted to secure the desired proportion between direct signal and total reverberation signal. The feedback voltage divider **224** (Fig. 1A) is then adjusted as required to give the desired reverberation characteristic within the limits of the system.

It has been found that for a given ratio of direct signal to total reverberation signal, the reverberation becomes less noticeable as the total volume level is lowered. Accordingly, a given ratio of direct signal to total reverberation signal which is satisfactory for one overall volume level may not be satisfactory when the volume level is changed. Accordingly, it is proposed, according to the invention, to gang the voltage dividers **10** (Fig. 1A) and **173** (Fig. 1B) and to design them to have nonlinear characteristics represented by the curves **234** and **235**, respectively, in Fig. 4, for example. In this fashion, the overall gain is substantially linear with respect to the setting of the gain control voltage divider **10**, while the proper emphasis of the reverberation signal at low overall volume levels is provided as required for natural reproduction.

If desired, the attentuators **107***a*, **108***a*, **109***a* and **110***a* to attenuate the respective signals from the pickup heads **107–110**, inclusive, appropriately may be ganged and designed to produce different mean reverberation characteristics other than the 2 second reverberation characteristic represented by the curve **231** in Fig. 3.

The invention thus provides novel and highly effective synthetic reverberation apparatus which enables reverberation characteristics closely approximating those obtainable in specified surroundings to be obtained. By using

an endless magnetic tape together with a plurality of pickup heads and a pickup head as described, together with feedback, it is possible to obtain very natural reproduction with apparatus of minimum size and weight.

While a specific form of the invention has been described herein and illustrated in the drawings by way of illustration, the invention is not to be limited thereto. Obviously, numerous modifications in form and detail are possible within the scope of the following claims.

I claim:

1. In synthetic reverberation apparatus, the combination of a direct signal channel having input terminal means adapted to receive an input signal and having output terminal means, and a reverberation signal channel comprising signal storage means, means responsive to said input signal for inserting in said storage means a representation of said input signal, a plurality of means responsive to said representation for producing a plurality of signals corresponding thereto, each of said signals being delayed in time from the others and being attenuated with respect to the preceding one, means setting the amplitudes of said respective signals to values corresponding to those required at the respective time occurrences of said time delayed signals for a selected normal reverberation decay characteristic, feedback means responsive to said representation for supplying a feedback signal to said inserting means to cause the insertion in said storage means of a representation corresponding thereto and the production by said respective representation responsive means of a second plurality of signals corresponding thereto, means permitting adjustment of said feedback signal over a range enabling adjustment of said second signals over ranges including values above and below those required at the respective time occurrences of said second signals for said selected reverberation characteristic, and means responsive to signals produced by said representation responsive means for combining a signal representative thereof with the signal output of said direct channel.

2. In synthetic reverberation apparatus, the combination of a direct signal channel having input terminal means adapted to receive an input signal and having output terminal means, and a reverberation signal channel comprising an endless, movable magnetic record strip, recording means responsive to said input signal for recording on said record strip a representation of said input signal, a plurality of pickup means spaced apart along said record strip at locations corresponding to different time delays with respect to said recording means for producing a plurality of signals, respectively, from said recorded representation, means for attenuating said respective signals to values corresponding to those required at the respective time occurrences of said signals for a selected normal reverberation decay characteristic, a feedback head mounted in operative relation to said record strip for producing a feedback signal corresponding to said recorded representation, adjustable gain means supplying said feedback signal to said recording means to cause the recording on said record strip of a representation corresponding thereto and the production by said pickup means of a second plurality of signals, respectively, said adjustable gain means permitting adjustment of said feedback signal over a range enabling said second signals to be adjusted over ranges including values above and below those required at the respective time occurrences of said signals for said selected reverberation characteristic, means for erasing said representation from said record strip, and means for combining signals produced by said pickup means with the output of said direct channel.

3. In synthetic reverberation apparatus, the combination of a direct signal channel having input terminal means adapted to receive an input signal and having output terminal means, and a reverberation signal channel comprising an endless, movable magnetic record strip, recording means responsive to said input signal for recording on said record strip a representation of said input signal, a plurality of pickup means spaced apart equal distances along said record strip at locations corresponding to different equal time delays with respect to said recording means for producing a plurality of signals, respectively, from said recorded representation, means for attenuating said respective signals to values corresponding to those required at the respective time occurrences of said signals for a selected normal reverberation decay characteristic, a feedback head mounted in operative relation to said record strip for producing a feedback signal corresponding to said recorded representation, adjustable gain means supplying said feedback signal to said recording means to cause the recording on said record strip of a representation corresponding thereto and the production by said pickup means of a second plurality of signals corresponding thereto, said adjustable gain means permitting adjustment of said feedback signal over a range enabling adjustment of said second signals over ranges including values above and below those required at the respective time occurrences of said second signals for said selected reverberation characteristic, means for erasing said representation from said record strip, and means for combining signals produced by said pickup means with the output of said direct channel.

4. In synthetic reverberation apparatus, a reverberation channel comprising an endless magnetic record strip, means for moving said strip at uniform speed, recording means adapted to receive an input signal to record a representation thereof on said strip, a plurality of pickup means spaced apart along said strip for generating a plurality of delayed signals in response to said recorded representation, separately adjustable attenuator means for adjusting the amplitudes of said respective delayed signals to values corresponding to those required at the respective time occurrences of said delayed signals for a selected normal reverberation decay characteristic, controllable gain means for feeding back one of said delayed signals to said recording means to cause the recording on said record strip of a representation corresponding thereto and the production by said pickup means of a second plurality of signals corresponding thereto, said controllable gain means permitting adjustment of said feedback signal over a range enabling adjustment of said second signals over ranges including values above and below those required at the respective time occurrences of said second signals for said selected reverberation characteristic, means for combining the signal outputs of said pickup means, and means for erasing said recorded representation from said record.

5. In synthetic reverberation apparatus, a reverberation channel comprising an endless magnetic record strip, means for moving said strip at uniform speed, recording means adapted to receive an input signal to record a representation thereof on said strip, a plurality of pickup means spaced apart along said strip for generating a plurality of delayed signals in response to said recorded representation, a plurality of separately adjustable attenuation means connected to attenuate the signal outputs of said respective pickup means to values corresponding to those required at the respective time occurrences of said delayed signals for a selected mean normal reverberation decay characteristic, controllable gain means for feeding back one of said delayed signals to said recording means to cause the recording by said recording means of a representation corresponding thereto and the production by said respective pickup means of a second plurality of signals corresponding thereto, said gain means being controllable over a range enabling adjustment of said second signals over ranges including values above and below those required at the respective time occurrences of said second signals for said selected reverberation characteristic, means for combining the signal out-

puts of said pickup means, and means for erasing said recorded representation from said record.

6. In synthetic reverberation apparatus, the combination of a direct channel having input terminals adapted to receive an input signal and including gain control means, a reverberation channel connected to receive said input signal and to introduce a reverberation signal component into said direct channel, and gain control means in said reverberation channel ganged to the direct channel gain control means and constructed so that the proportion of reverberation signal component to direct signal is varied as a function of the overall volume level.

7. In synthetic reverberation apparatus, the combination of a direct channel having input terminals adapted to receive an input signal, voltage divider means connected in said channel, a reverberation channel connected to receive said input signal and having voltage divider means therein, and mixer means connected to receive signal inputs from both of said voltage divider means, said voltage divider means having complementary nonlinear characteristics such that the ratio of reverberation signal component to direct signal varies inversely with the overall gain of the apparatus.

8. In synthetic reverberation apparatus, the combination of a direct channel having input terminals connected to receive an input signal and including first voltage divider means, an endless magnetic record strip, means for advancing said record strip, means responsive to said input signals for recording a representation thereof on said record strip, a plurality of pickup means mounted

in fixed spaced relation to said record strip for generating a plurality of successively delayed signals from said recorded representation, means for attenuating said delayed signals to values in correspondence with those required at the respective time occurrences of said delayed signals for a predetermined mean normal reverberation decay characteristic, an amplifying channel connected to receive said attenuated signals and including second voltage divider means, feedback channel means connected to receive one of said attenuated signals and including third voltage divider means, means introducing the output of said third voltage divider means into said recording means to cause the recording on said record strip of a representation corresponding to the output of said third voltage divider means and the production by said respective pickup means of a second plurality of signals corresponding thereto, said third voltage divider means permitting adjustment of the feedback signal over a range enabling adjustment of said second signals over ranges including values above and below those required at the respective time occurrences of said second signals for said selected reverberation characteristic, and means introducing the output of said second voltage divider means into said direct channel.

References Cited in the file of this patent

UNITED STATES PATENTS

2,105,318	Goldsmith	Jan. 11, 1938
2,493,638	Olson	Jan. 8, 1950