May 6, 1947. C. M. SINNETT 2,420,204

METHOD OF AND SYSTEM FOR ENHANCING SOUND REPRODUCTION

Filed Sept. 21, 1944 2 Sheets-Sheet 1

Fig. 1.

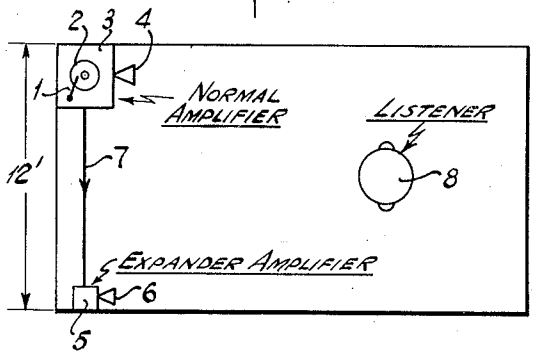
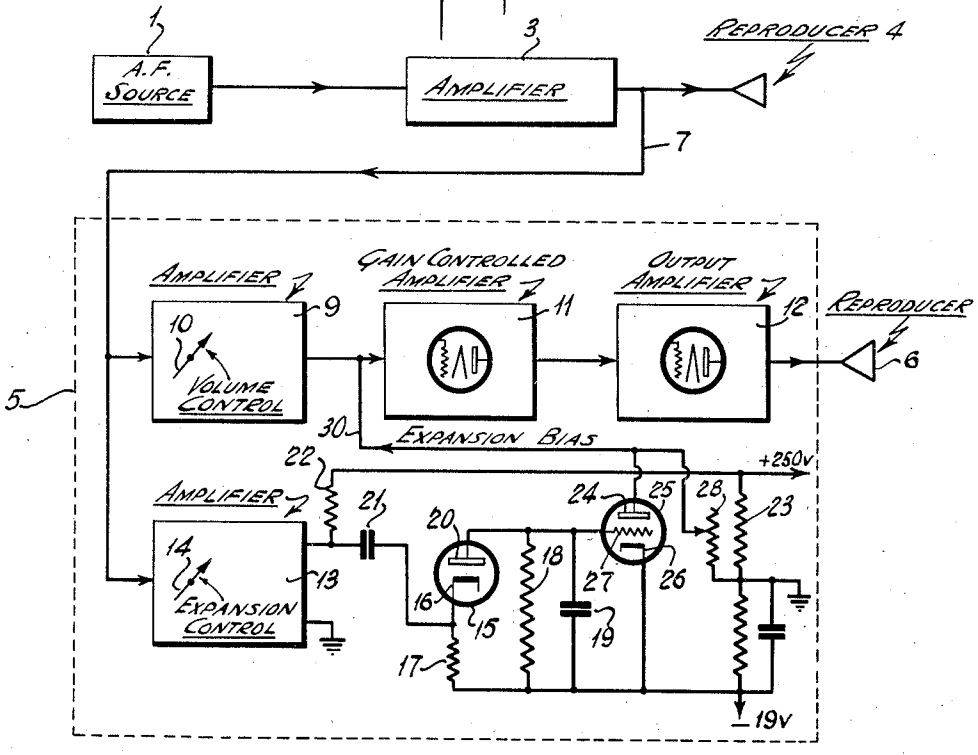


Fig. 2.



INVENTOR
CHESTER M. SINNETT.
BY H.S. Grover
ATTORNEY

May 6, 1947. C. M. SINNETT 2,420,204

METHOD OF AND SYSTEM FOR ENHANCING SOUND REPRODUCTION

Filed Sept. 21, 1944 2 Sheets-Sheet 2

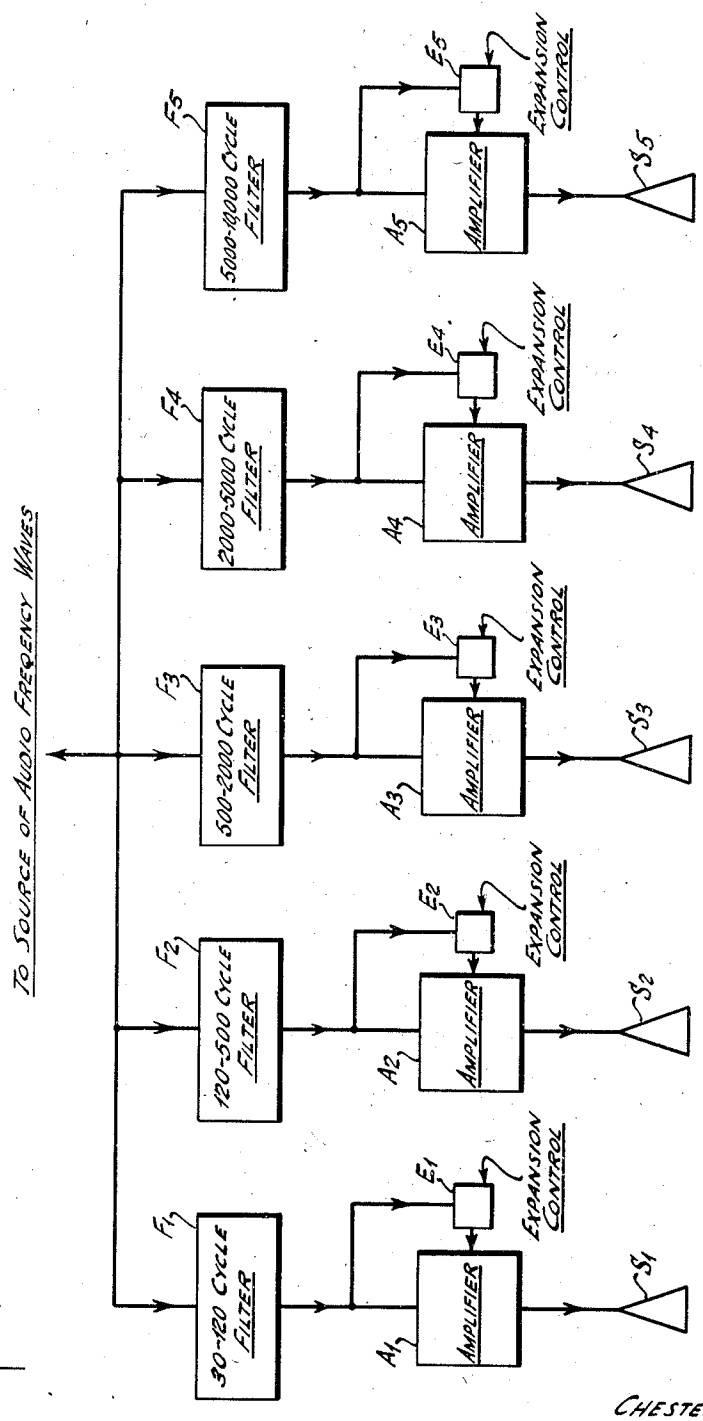


Fig. 3.

INVENTOR
CHESTER M. SINNETT.
BY H. S. Snover
ATTORNEY

Patented May 6, 1947 2,420,204

UNITED STATES PATENT OFFICE

2,420,204

METHOD OF AND SYSTEM FOR ENHANCING SOUND REPRODUCTION

Chester M. Sinnett, Westmont, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application September 21, 1944, Serial No. 555,131

9 Claims. (Cl. 179—1)

1

My present invention generally relates to a novel method of, and means for, enhancing sound reproduction, and more particularly to novel improved systems for providing synthetic reverberation.

When a listener is in the same room in which a group of instruments are being played he will, if the room is at all suited for musical reproduction, hear but a small portion of the total sound as direct radiation. Probably 90% of the sound energy which reaches his ears will have been reflected from room surfaces, such as the walls and the like. This reflected sound will reach his ears later, and from a different direction than the directly radiated sound waves. Apparently the listener is not satisfied if this is not the case. Indeed, experience has taught that there is a different optimum reverberation for each room, and an optimum size room for each type of musical presentation.

"Reverberation" in a room consists of the multiple reflection of a large number of pencils of sound, and each pencil of sound suffers a decrease in intensity with each reflection. The human hearing mechanism is so constructed that it can localize sounds with great accuracy. This property is due to two effects, namely: the difference in intensity and the difference in phase between the two ears of a listener. This characteristic of the human hearing mechanism has been termed the "binaural" characteristic. Due to the binaural sense there is a condiserable difference between sound arriving at the ears of a listener at respectively different times and from respectively different directions as distinguished from sound of the same total amplitude arriving from a single source. This can be demonstrated by placing a microphone in a room having high reverberation and employing it to listen from outside to a person speaking within the room. Due to reverberation in the room it may be difficult to understand speech over the microphone, whereas no such difficulty has been encountered when the listener himself was also in the room.

When a single microphone is used with an orchestra, similar defects are noted. A microphone in the same location that would be selected for good direct listening position will pick up more "room" (that is to say, reverberation effects in the form of multiple reflection of sound) than is considered desirable. To overcome this the microphone may be placed closer to the orchestra. If, now, a record is made of the microphone output in its position close to the orchestra (that is at the point where direct sounds predominate), reproduction of such a record seems flat and lacking in perspective. The sound reproduction lacks the reverberation effects which would have satisfied the listener had he been in the room with the orchestra. On the other hand, if the record is made with the microphone located at a point where reflected sounds predominate, the recorded sound is bad and very "vowelly." This is due to the fact that the microphone picks up a considerable amount of reflected sounds and misses the direct sounds.

2

Accordingly, it is one of the main objects of my present invention to provide a novel method of heightening sound perspective during record reproduction, microphone reproduction or even radio reproduction, by enhancing the reproduction of the sound waves in such a way that the binaural characteristic of the human hearing mechanism is catered to.

Assuming that the source of sound waves is one wherein the record, microphone or radio studio microphone is capable of providing sound waves in which "direct" waves predominate over reflected sound waves, another object of my invention is the provision of a method of synthetic reverberation wherein a plurality of sound reproducer devices are spaced in a predetermined relation with respect to the listener. The reproducers are supplied with audio frequency waves through separate channels, and at least one of the channels is provided with dynamic range expansion whereby it is possible to enhance the reproduction, particularly in the case of symphonic orchestral music, church choirs and the like.

Another object of my invention is to provide a method of producing sound enhancement for phonograph or radio reproduction wherein the audio frequency waves are applied to a plurality of audio channels, each of which passes a predetermined different band of audio frequencies and is provided with an expander amplifier whereby the various portions of the audio frequency range may be expanded at different times and in varying proportions depending on the general frequency bands being reproduced, thereby giving the effect of perspective.

Another important object of this invention is to provide a simplified method of adding to the perspective of sound reproduction wherein there is employed a single normal audio frequency amplifier for feeding its amplified audio waves to its own loudspeaker, and a second loudspeaker spaced from the first loudspeaker and fed with the audio waves through an expander amplifier which

is operated so that on loud passages the second loudspeaker produces sound, thereby providing enhanced sound reproduction due to the fact that the binaural characteristic of the listener's hearing is catered to.

Still other objects of my invention are to improve generally the reproduction of sound, and more specifically to provide reliable, efficient and economical circuits for producing synthetic reverberation effects in a room.

Other objects and features of my invention will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing—

Fig. 1 schematically shows a plan view of a room wherein there is installed a system embodying the present invention;

Fig. 2 is a partially schematic view of a preferred system employing the invention; and

Fig. 3 schematically shows a modification of the invention.

Referring now to Fig. 1 of the drawings, there is shown a room in which is located a phonograph pickup 1; a turntable carrying a record 2; an amplifier 3; and a reproducer such as a loudspeaker 4. It will be understood that the room is shown in plan view. Assuming that the normal amplifier and loudspeaker are located in one corner, an amplifier 5 of the expander type is located in the opposite corner. A transmission line 7 is provided to feed signal energy from the normal amplifier to the expander amplifier 5. The loudspeaker 6 reproduces the expanded signal output of amplifier 5. By way of example it is assumed that the distance between reproducers 4 and 6 is about 12 feet. This is not a critical distance, but rather a working spacing. The listener 8 is located so as to hear the sound waves emitted from both reproducers 4 and 6.

As pointed out before, the main purpose of the system shown in Fig. 1 is to cater to the binaural sense of the listener's ears. The audio frequency waves fed to amplifiers 3 and 5 could, of course, be derived from the output circuit of a radio receiver detector, or from the microphone of a public address system. In general, on loud passages of the signals fed to amplifier 3 the second reproducer 6 produces sound thereby heightening the sound "perspective" at the listener 8. The function of expander amplifier 5 is to reproduce the reverberant sound separately from the direct sound from amplifier 3. The optimum "build-up" and reverberation time for various rooms, music and speech have been determined. See, for example, Benecke (Analen der Physick, Aug. 1930) that the "build-up" time for all rooms should be 0.06 second, and that the ratio of reverberant to direct sound should be as large as possible for any given size room without exceeding the optimum build-up time. Fulfillment of these two requirements results in an optimum reverberation time varying as the cube root of the volume, if the process is all in air. However, with an electrical reproducing system there is no restriction to the cube root law, but may follow the fundamental requirements as formulated by Benecke. The system shown in Figs. 1 and 2 permits a listener to receive seemingly "enhanced" reproduction of symphony orchestra music and church choirs.

In Fig. 2 I have shown the details of one form

of expander amplifier that may be employed for the spaced "reverberation" speaker 6. It will be understood, of course, that the invention is in no way restricted to the specific expander system shown. The audio signal source 1 feeds its signal voltage to amplifier 3, and speaker 4 reproduces the sound. The transmission line 7 may derive its input signal energy for expansion amplifier 5 (shown in the dotted rectangle) from the voice coil of the speaker 4.

There are two channels within rectangle 5. The controlled amplifier channel consists of schematically-represented amplifier 9 which is preferably provided with a manually-adjustable volume control device 10. This may be, for example, a potentiometer across the input electrodes of the first tube in amplifier 9. The signal output energy of amplifier 9 is fed to controlled amplifier 11 whose gain is to be regulated in an expanding sense. The amplifier 11 may, if desired, include a pair of tubes in push-pull arrangement. The signal output of amplifier 11 may be amplified further at stage 12, which may be another push-pull stage. The speaker 6 is driven by the amplified output of amplifier stage 12. Amplifiers 11 and 12 are schematically represented.

The second channel, or expander portion of the system, comprises a schematically-represented amplifier 13. The amplifier has an expansion control device 14, which may be a potentiometer across the input electrodes of the amplifier 13. The signal output of amplifier 13 is rectified and filtered. The rectifier consists of a diode 15 whose cathode 16 is connected by resistor 17 to a point of negative D. C., say −19 volts. The load resistor 18, shunted by condenser 19, is connected between the anode 20 and lower end of resistor 17. The coupling condenser 21 passes the audio signals fed to the cathode 16 of diode 15, and also blocks the direct current in the preceding plate circuit of the amplifier 13. Plate voltage is supplied to the plate of prior amplifier 13 by virtue of the connection, including resistor 22, from the +250 volts end of the voltage supply bleeder resistor 23. The ground on the bleeder resistor 23 may be established at a point such that the upper section is 5500 ohms against a lower section of 180 ohms.

The plate 24 of the direct current amplifier tube 25 is connected to the ground point on resistor 23 by means of an adjustable plate resistor 28. The cathode 26 is returned to the −19 volts end of resistor 23, and control grid 27 is connected directly to the anode end of resistor 18. The expansion bias is applied from the plate 24 of tube 25 to the control grid of the controlled amplifier 11. The variable resistor 28 determines the degree or amount of dynamic range expansion which is to be secured.

The rectified voltage at the output of diode 15 is applied to grid 27, after suitable filtering, in a negative sense. The plate current of tube 25 is, therefore, decreased. Since the tube 25 operates with +B at ground, the voltage drop across plate resistor 28 provides a negative voltage which is most negative at zero signal. In other words, when zero audio signal is applied to rectifier 15, the space current flow of the tube is a maximum thereby rendering the voltage applied over line 30 most negative. Hence, the gain of amplifier 11 is a minimum. Of course, the expansion control 14 may be adjusted to predetermine the zero signal level for rectifier 15. Further, the potentiometer 28 may be adjusted to predetermine the

maximum negative voltage which can be developed for control of amplifier 11.

As the audio signal to rectifier 15 increases the negative voltage of grid 27 increases, and the current flow through tube 25 decreases. Hence, the voltage across resistor 28 falls, and thereby reduces the negative bias applied to amplifier 11. This results in a gain increase, or volume expansion, of amplifier 11. The variable resistor 23 will now be seen to provide a direct control over the amount of expansion. With the resistors all in, the maximum amount of expansion could be about 14 decibels. The expansion can never exceed a predetermined amount, as after the direct current ouput tube 25 is cut off a further increase in signal level does not change the bias over line 30. The expander volume control 14 sets the level at which expansion takes place. By way of example it is pointed out that an expansion up to 14 decibels can be secured up to an input voltage of the order of 0.5 volt. The listener will find the provided range of control and adjustments satisfactory for securing sound enhancement of the phonograph or radio signal output. The requisite amount of expansion may be set up by ear or meter.

In Fig. 3 I have schematically shown a system for securing the desired "reverberation" effects on a frequency response basis. In general, a plurality of signal transmission channels is provided. Each channel passes a different band of audio frequencies, and each channel includes a respective dynamic range expander. Various portions or frequency bands of the entire range may thus be expanded at different times depending upon the general frequency bands being reproduced. In this way, the effect of "perspective" or realism is approached. More specifically, in Fig. 3 the source of audio frequency waves (not shown) is connected to a plurality of audio frequency filters of the band pass type. The filters F_1 to F_5 inclusive pass respectively 30 to 120 cycles; 120 to 500 cycles; 500 to 2000 cycles; 2000 to 5000 cycles; 5000 to 10,000 cycles. Each filter has its output terminals coupled to a respective one of amplifiers A_1 to A_5. The amplified signal output of each of amplifiers A_1 to A_5 is reproduced by a respective one of a plurality of loudspeakers S_1 to S_5. Hence, when there is delivered from the audio frequency wave source signals covering the entire range up to 10,000 cycles, each of speakers S_1 to S_5 will be delivering sound output. Should any particular one of the predetermined bands of audio frequencies be missing, the associated speaker would not be providing sound waves of that one band.

Each of amplifiers A_1 to A_5 is controlled by a dynamic range expansion control circuit E_1 to E_5. The expansion controls E_1 to E_5 are schematically represented, because those skilled in the art to which this invention pertains are fully acquainted with the manner of expanding the dynamic range of an amplifier in accordance with the intensity level of the amplifier signal input. Each expansion control would derive signal energy of the particular band of audio frequencies from the amplifier input. The expansion control could, for example, include a rectifier whose output voltage, after suitable filtering, would be proportional to the amplifier input level. The rectified voltage could then be applied to a gain control electrode of the amplifier in a gain-increasing sense. Fig. 2 shows but one of many ways for securing such gain expansion of an amplifier.

It will now be seen that various frequency portions or bands of the entire audio range would be expanded at different times, depending on the intensity level at the output of each of filters F_1 to F_5. Should, for example, the 120 to 500 cycle band become dominant (as in an emphasized bass passage), the amplifier A_2 would be increased in gain by the expansion control E_2. This would heighten the "perspective" of reproduction, as the listener would apparently hear the emphasized bass in the reproduced rendition just about in the same manner as in a room. The expanded output of S_2 would be giving a reverberation effect that would seem natural to the listener. Similarly, if there were playing a single instrument whose notes were in the 500 to 10,000 cycle band (say a flute), the output of A_5 would be expanded and the sound output of S_5 would create the illusion of reverberation and increase the enjoyment of listening to music reproduction.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention.

What I claim is:

1. A method of producing sound enhancement for audio frequency wave reproduction, which includes the steps of applying the waves to a plurality of audio frequency transmission channels each of which passes a predetermined band of audio frequencies, and expanding the gain of each channel in accordance with the intensity level of the signals transmitted by each channel whereby the various portions of the audio frequencies range may be expanded at different times depending on the audio frequency content of said waves.

2. In a system for adding to the perspective of sound reproduction, a first audio frequency amplifier provided with a sound reproducer, a source of audio frequency waves coupled to the input of said amplifier, a second amplifier provided with its respective reproducer, means for applying waves amplified by said first amplifier to the input of the second amplifier, and means electrically connected with said second amplifier for expanding the gain of the latter whereby on loud passages the second reproducer produces sound thereby providing enhanced sound reproduction.

3. A method of creating the illusion of reverberation during the reproduction of audio frequency waves, which includes the steps of normally amplifying the waves, reproducing the amplified waves at a given location relative to a listener, separately amplifying said waves, automatically expanding the separate amplification of said waves in response to the amplitude level of said waves exceeding a predetermined magnitude, and separately reproducing the expanded waves at a predetermined different location relative to said listener whereby said reverberation effect is produced.

4. In combination with a source of signals, a first amplifier having input terminals and output terminals, means for applying signals to said input terminals, a first reproducer connected to said output terminals, a second amplifier provided with said input terminals connected to said first amplifier, a second reproducer connected to the output of the second amplifier, and a dynamic range expansion circuit responsive to the output

of said first amplifier for automatically increasing the gain of the second amplifier.

5. In combination with the source of audio frequency waves, a plurality of audio frequency band pass filters, said filters being adapted to pass respectively different bands of audio frequencies, a plurality of amplifiers, each amplifier being connected to a respective one of said filters, a plurality of sound reproducers, each reproducer being connected to a respective one of said amplifiers, and a separate amplification expansion control circuit electrically connected with each respective one of said amplifiers.

6. A system for producing sound enhancement for audio frequency wave reproduction which includes means for applying audio waves to a plurality of audio frequency transmission channels, each of which channel passes a predetermined band of audio frequencies, and means expanding the gain of each channel in accordance with the intensity level of the signals transmitted by each channel whereby the various portions of the audio frequencies range may be expanded at different times depending on the audio frequency content of said waves.

7. In a system for adding to the perspective of sound reproduction, a first normal audio frequency amplifier provided with a sound reproducer, a source of audio frequency waves coupled to the input of said amplifier, a second amplifier provided with its respective reproducer, means for applying waves from said source to the input of the second amplifier, and rectifier means electrically connected with said second amplifier for expanding the gain of the latter whereby on loud passages the second reproducer produces sound

thereby providing enhanced sound reproduction.

8. A method which includes the steps of amplifying audio waves, reproducing the amplified audio waves at a given location relative to a listener, separately amplifying said audio waves, automatically expanding the dynamic range of said separately amplified waves in response to the amplitude level of said waves exceeding a predetermined magnitude, and separately reproducing the expanded waves at a predetermined different location relative to said listener whereby said reverberation effect is produced.

9. In combination with a source of audio frequency signals, a first audio amplifier having input terminals and output terminals, means for applying audio signals to said input terminals, a first reproducer connected to said output terminals, a second amplifier provided with input terminals connected to said first amplifier, a second reproducer connected to the output of the second amplifier, and a gain expansion circuit responsive to the output of said first amplifier for automatically increasing the gain of the second amplifier.

CHESTER M. SINNETT.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,352,696	DeBoer et al.	July 4, 1944
2,126,929	Snow	Aug. 16, 1938
2,137,032	Snow	Nov. 15, 1938