Aug. 3, 1948. S. J. BEGUN 2,446,479

METHOD AND APPARATUS FOR CORRECTING PHASE SHIFT DISTORTION IN SOUND RECORDING SYSTEMS

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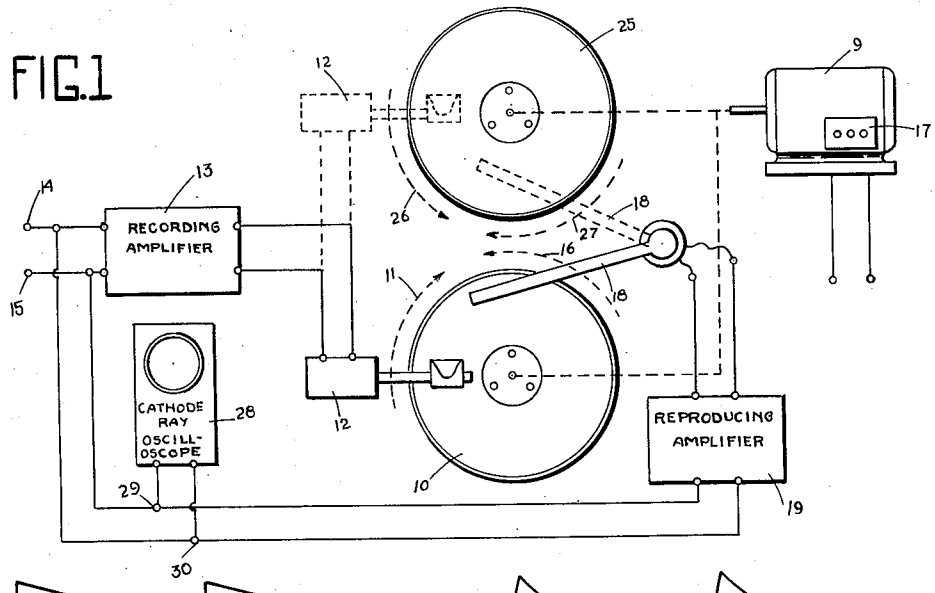
FIG.1



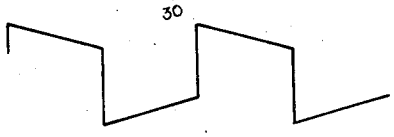


FIG.2

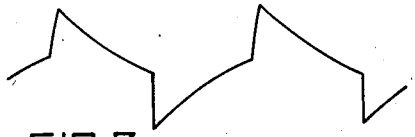


FIG.3

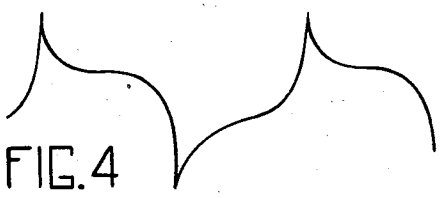


FIG.4

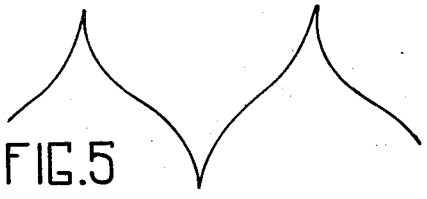


FIG.5

FIG.6

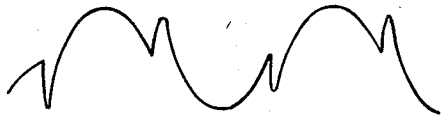


FIG.7

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METHOD AND APPARATUS FOR CORRECTING PHASE SHIFT DISTORTION IN SOUND RECORDING SYSTEMS

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8 Claims. (Cl. 179—100.1)

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My invention pertains to recording and reproducing devices and more particularly to a method of reducing or eliminating time shift or phase shift distortion in a signal introduced by the recording and/or reproducing process.

An object of my invention is to reduce the amount of undesired phase shift distortion in a signal which has been recorded and reproduced.

Another object of my invention is to substantially balance out undesired phase shift in a recording-reproducing system.

A further object of my invention is to establish a phase shift distortion in a signal which is equal to and of an opposite sense from an undesired phase shift in the signal, and to thereby substantially cancel the undesired phase shift.

It is also an object of my invention to provide a recording system which substantially cancels phase shift distortion in the signal.

Figure 1 diagrammatically illustrates a device for practicing my invention.

Figure 2 illustrates a signal which may be applied to the input of the device illustrated in Figure 1.

Figure 3 illustrates the same signal after it has been distorted by the recording amplifier.

Figure 4 illustrates the signal of Figure 3 after it has been distorted due to phase shift in both the recording and reproducing circuits.

Figure 5 illustrates the signal of Figure 4 after passing through the recording equipment for the second time.

Figure 6 illustrates the signal of Figure 5 after passing through the complete recording-reproducing equipment twice in accordance with my invention.

Figure 7 illustrates the appearance of the signal of Figure 2 if conventional recording and reproducing processes are used.

My means and method for recording and reproducing a signal with little or no undesired time or phase shift between frequencies is generally applicable to all recording and reproducing systems including film, magnetic tape, and disk. It is described in connection with a disk recording system but this is not to be construed as a limitation on the scope of the invention which is to be limited only by the claims and the prior art.

In recording and reproducing systems there are three requirements that must be satisfied in order that an exact facsimile of a recorded signal can be reproduced. One; there must be no amplitude distortion (flat frequency response). Two; there must be an absence of harmonic distortion. Three; there must be no time shift between frequencies (no phase shift). Practically all previous work in film, tape, and disk recording and reproducing has been in connection with the first and second requirements which have been considered more important for acoustical excellence than the third requirement. The average human ear seems to tolerate considerable phase shift in the reproduced signal without noticing severe effect on the quality of the reproduction. In instrument work, such for example as a transient analyzer (see my application Serial No. 399,909, now abandoned), the phase relation between two components of one signal are of great importance. For this type of work the undesired phase shift should be reduced to a minimum. The device and method illustrated in Figure 1 substantially cancels the undesired phase shift which may be present in recording and reproducing a signal, thereby establishing a signal which, in effect, has no phase shift.

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The device illustrated in Figure 1 comprises a first phonograph disk 10 of recording material which is driven in the direction of the arrow 11 by a motor 9. A recording head or cutter mechanism 12 is associated with the disk 10 and receives a signal from the recording amplifier 13. The input terminals 14, 15 of the recording amplifier 13 are adapted to be connected to a source of signal such for example as the source of a transient. The recording amplifier 13 and the recording head 12 each may introduce phase shift distortion into the signal which is applied at terminals 14, 15. This phase shifted signal is recorded on the disk 10 by any of the conventional means or methods. After the signal has been recorded the direction of rotation of the disk 10 is reversed so that it moves in the direction of arrow 16. This reversal may be effected by any means, such for example by switch 17. A phonograph pickup 18 is provided adjacent the disk 10 and is adapted to convert the signal recorded thereon back into a variable electrical impulse. It is to be remembered that due to the reversal of the direction of motion of the disk 10 and the various phase shift distortion introduced, the output from the pickup 18 will not be the same as the input to the recording head 12. The output from the pickup head 18 is amplified by the reproducing amplifier 19 and is connected to the input of the recording amplifier 13. Both the pickup 18 and the reproducing amplifier 19 may introduce further phase shift distortions in the signal.

The motor 9 also drives another phonograph disk 25 of recording material in the direction of the arrow 26. The recording head 12 is swung over into the dotted position and records on the disk 25 the reversed signal which the pickup 18 while operating on disk 10 feeds to the recording amplifier 13. When the reversed signal has been recorded the direction of rotation of the disk 25 is reversed to that indicated by the arrow 27, and the pickup arm 18 is swung into its dotted position and reproduces the recorded signal. The signal is amplified by the amplifier 19 and appears at the oscilloscope 28, or some other suitable device. Due to reverses of the direction of rotation of the disks 10 and 25 the signal output from the pickup 18 is reproduced in proper sequence. That is, it is not backward as it was when reproduced from the disk 10, and due to the signal passing through each phase shifting unit twice, once in a forward direction and once in a reverse direction, the phase shift has been substantially cancelled out.

The principle of canceling undesired phase shift distortion by the method as described above is as follows: For reasons of simplicity in the explanation the assumption is made that the recording head and the recording amplifier form a unity which introduces a time delay distortion L, which is a function of frequency. On the same basis the assumption is also made that the reproducing head and the reproducing amplifier form another unity which introduces a time delay distortion N, which again is a function of frequency. The over-all time delay of the recording and reproducing process when operated in a normal manner may, therefore, be expressed as the form $L+N+T$. T is the time delay which is introduced by the time interval between recording and reproducing, and is independent of frequency. For this reason T can be neglected in this consideration.

Since in my system, after the signal has been recorded, the record is reproduced in reverse direction, the portion of the signal which was recorded first will be reproduced last, and therefore the signal obtained on the output terminals of the recording amplifier will include an undesired time shift distortion represented by $N-L$. If this distorted signal is recorded again using the same recording amplifier and the same cutter, or another recording amplifier and another cutter of equal electrical and mechanical characteristics, the signal obtained on the second disk will have an undesired time shift represented by $(N-L)+L=N$. Since for final reproduction in my system, the direction of rotation of the record is reversed again, the time shift originally existing on the record as N, appears now reversed as —N and therefore is cancelled in the second reproduction which introduces a time shift +N. Thus the over-all time shift which was a function of frequency is completely cancelled. To obtain such a cancellation of the time shift N, either the same pickup and reproducing amplifier, or a pickup and reproducing amplifier of characteristics similar to those of the pickup and reproducing amplifier used for the first reproduction, should be used. To obtain perfect results, the disks used in both processes must also be equal in their characteristics. In other words, all the elements must be duplicated in the second recording, otherwise incomplete cancellation will take place.

In Figures 2 to 7, which represent signals which have been obtained by using one particular disk recording equipment, this process of time shift cancellation is illustrated. Figure 2 represents the signal applied to terminals 14 and 15, and Figure 3 represents the signal after it has passed through the recording amplifier (13) and appears on the terminals of the recording mechanism (12). After reversing the direction of disk (10), a signal which is represented by Figure 4 is obtained on the output terminals of the reproducing amplifier. This signal is fed through the recording amplifier 13 and appears as shown in Figure 5 on the terminals of the recording mechanism 12. After the direction of rotation of disk 25 has been reversed the signal picked up from it by pickup head 18 looks as represented by Figure 6, this is a close facsimile of the signal which originally was fed to the input terminals, (14) and (15). Its slight waviness is explained by the fact that some rumble was present in the reproducing equipment. If one would have followed the conventional method of re-recording, in which no reversals are present, the original signal represented by Figure 2 would have been changed to the signal represented by Figure 7 on the output terminals (29) and (30). The difference between the signals shown in Figure 6 and Figure 7 illustrates clearly the significance of my invention.

Though the particular value of this invention is most obvious when applied to recording and reproducing transient phenomena, it has also great significance if used to obtain for certain recording purposes a high signal-to-noise ratio. Peak amplitudes of complex wave forms may be greatly reduced in the recording process thus permitting to make better use of the available range of the recording device. To express it in other words, the ratio of maximum peak height to average recording level may be made much smaller by selecting a proper phase shifting network. Since complete cancellation of time shift in the recording and reproducing process takes place independently of the circuit elements involved as long as resonance conditions are avoided, the designer of equipment of this kind has great liberty in selecting a particular network for a particular application.

If my system is used for recording and reproducing speech, music, and other signals in which the order of the signal during final reproduction is important, care must be exercised to reverse the direction of rotation of the record medium a sufficient number of times to cause the output signal to be reproduced in proper order. If, however, a transient signal such as is illustrated is to be recorded and reproduced, it may not be important that the first part of the signal appear on the left side of the oscilloscope screen. In this case the final reproduction of the signal may be backwards so long as the phase distortion has been cancelled out.

My invention is particularly useful in systems wherein an equalizer network or networks is used in order to obtain a flat frequency response. These networks may introduce phase shift of the signal, but due to my system this phase shift is balanced out.

Although I have described my invention with a certain degree of particularity, it is to be understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim as my invention:

1. A dubbing system comprising, in combination, a first record medium, means for driving said record medium in a forward direction, means for recording a signal on said record medium during forward movement thereof, means for reversing the direction of movement of the record medium, reproducing means for reproducing the recorded signal during reverse movement thereof, a second record medium, means for driving said second record medium, means for recording during forward movement of the record medium a signal substantially corresponding to the signal reproduced from the first record medium, means for reversing the direction of movement of the second record medium, and means for reproducing the recorded signal during reverse movement of the said second record medium, said means for recording on said two record mediums having substantially the same phase shift qualities and said means for reproducing from said two record mediums having substantially the same phase shift qualities.

2. A device as set forth in claim 1 in which the two recording means are the same unit, and in which the two reproducing means are the same unit.

3. A device as set forth in claim 1 in which the two recording means are different units having substantially the same electrical and mechanical characteristics, and in which the two reproducing means are different units having substantially the same electrical and mechanical characteristics.

4. In a recording and reproducing system, a first signal carrier; a first signal channel including a recording amplifier and signal recording means for recording a signal on said signal carrier; a second signal carrier having substantially the same phase shifting characteristic as said first signal carrier; a second signal channel including signal pickup means, amplifier means, and signal recording means for transmitting the signal from said first signal carrier to said second signal carrier in reverse sequence, and a third signal channel including signal pickup means, and amplifier means for reproducing the signal from said second signal carrier in forward sequence, the combined phase shift introduced into said signal by said first and third signal channels being equal to but having an opposite sense than the phase shift introduced into said signal by said second signal channel.

5. The system as set forth in claim 4 in which the recording amplifier and signal recording means in the first signal channel are included in the amplifier means and the signal recording means in the second signal channel.

6. The system as set forth in claim 4 in which the signal pickup means in the third signal channel is the same as the pickup means in the second signal channel.

7. The system as set forth in claim 4 in which the recording amplifier and signal recording means in the first signal channel are included in the amplifier means and the signal recording means in the second signal channel, and in which the signal pickup means in the third signal channel is the same as the pickup means in the second signal channel whereby the signal which is recorded and reproduced passes through each of the phase shifting means twice, once in a forward sequence and once in a reverse sequence.

8. The method of substantially eliminating signal phase shift distortion in the reproduction of a signal which comprises the steps of: introducing a first phase shift into said signal by recording it on a record medium moving in a forward direction, introducing a second phase shift into said signal by reproducing it from said record medium with said record medium moving in the reverse directon, introducing a third phase shift into said signal by recording it on a second record medium moving in a given direction, introducing a fourth phase shift into said signal by reproducing it from said second record medium with said record medium moving in a reverse direction from said given direction, said first and third phase shifts substantially cancelling each other, and said second and fourth phase shifts substantially cancelling each other, and controlling the rate of motion of said record medium so that it has substantially the same rate of motion during all of the steps of introducing phase shift.

SEMI JOSEPH BEGUN.

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