

Aug. 5, 1947.

D. E. SUNSTEIN

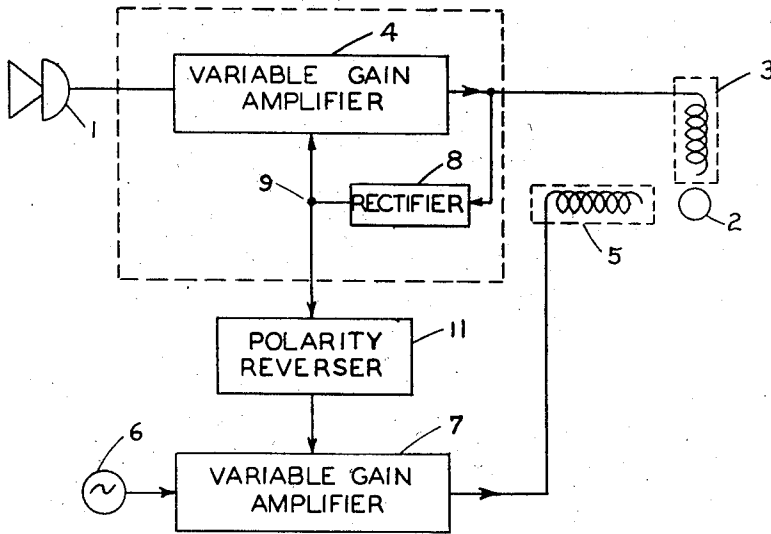
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MAGNETIC WIRE TELEGRAPHOPHONE SYSTEM

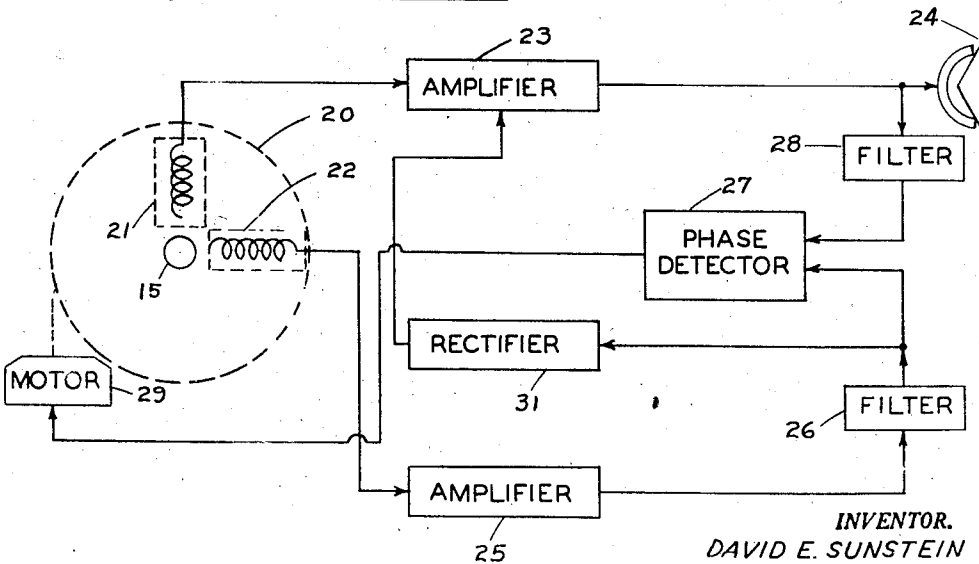
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2 Sheets-Sheet 1

Fig. 1



F-19. 2



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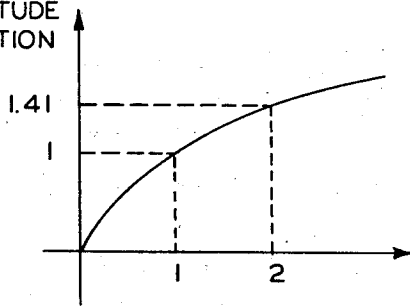
MAGNETIC WIRE TELEGRAPHOPHONE SYSTEM

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Fig. 3

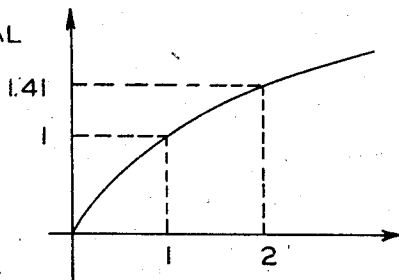
RELATIVE AMPLITUDE
OF MAGNETIZATION



RELATIVE AMPLITUDE OF
SOUND BEING RECORDED

Fig. 4

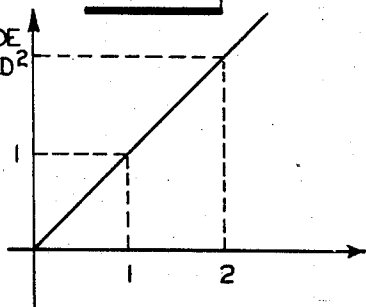
CARRIER SIGNAL



RELATIVE AMPLITUDE OF
SOUND BEING RECORDED

Fig. 5

RELATIVE AMPLITUDE
OF SOUND REPRODUCED²



RELATIVE AMPLITUDE OF
SOUND BEING RECORDED

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MAGNETIC WIRE TELEGRAPHOPHONE
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Application May 5, 1945, Serial No. 592,101

16 Claims. (Cl. 179—100.2)

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My invention relates to the recording of speech or other intelligence upon steel wire. More specifically, it relates to methods for compressing the amplitude of such a recording and for expanding the amplitude upon reproduction in accordance with the amount of compression.

One of the difficulties in recording speech, sound or other intelligence upon a steel wire arises in faithfully reproducing the intensity of the sound being recorded, due to the fact that variations in intensity cannot be easily accommodated upon the steel wire. Consequently, it becomes necessary, when recording, to provide means for preventing wide variations in intensity of the sound being recorded.

This is done by a volume control in which wide variations in intensity are reduced to smaller variations in intensity, as the speech or sound or music is recorded. Usually, these volume controls do not change the actual intensity of the instantaneous electrical vibrations or sound vibrations, but instead they change the average intensity of the vibrations.

When a record which has been made in this manner is reproduced, it will have a certain amount of volume compression, since the reproducing mechanism may not reproduce the same variations in intensity as were present in the original sound. This results in an unnatural reproduction due to the lack of faithful recording.

If it is desired to reproduce high quality sound such as symphony music, it becomes highly desirable that the intensity level of reproduction be the same as that of the music being recorded, or at least that the variations in intensity level correspond to the variations in intensity level of the music which was recorded. This may be accomplished with a volume expander in the receiver if this volume expander is properly matched to the compressor in the recorder.

It is the purpose of my invention to provide a novel means whereby the expansion in the receiver is automatically controlled in accordance with the pilot signal which is used in a recording partially for this purpose and partially for the purpose of maintaining the orientation of the pick-up coils at right angles to the orientation of the recording on the wire as compensation for twist in the wire. This second use of carrier frequency has been described in my co-pending application Serial No. 591,675, filed May 3, 1945.

In order that the carrier signal may supply information regarding the proper amount of expansion to be used, it is necessary that the strength of the carrier signal shall be propor-

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tional to the amount of volume compression which was used in the recording of the sound. This strength of carrier signal then can be utilized to control the amount of volume expansion used in the reproducer.

Still another method which might be somewhat more straightforward would be to make the strength of the carrier signal proportional not to the amount of compression used, but to the amount of expansion required in the receiver or reproducer. Under these circumstances, all that is necessary is that the reproducer have in it suitable filters and suitable automatic volume control equipment which is operative from this carrier frequency and which is then used as a volume expander or compressor as the case may require.

In accordance with my invention, as a record is made, the pilot signal which is used to orient the reproducer in accordance with the twisting of the wire, is also made to vary in amplitude with the amount of volume compression which is used in the amplifier of the recording system. Thus, for example, when the sound which is put into the microphone doubles, the sound recorded on the wire may be increased only by 41%, and at the same time the carrier signal which is put into the wire will indicate that the sound as picked up from the wire by the reproducing coil must be multiplied by a factor of 1.41 in order that the sound coming out of the loudspeaker shall be twice as large as the first sound which we mentioned.

In the reproducer this carrier signal is used to control the gain of an amplifier, and the signal which is picked up by the pick-up coil feeding this amplifier is multiplied by 1.41 in addition to whatever nominal gain is required in this amplifier. Thus, the output of the loudspeaker has been doubled. A factor of 41% of this output of the loudspeaker has arisen from the fact that the signal on the wire was increased by a factor of 41%. The rest of the increase to a factor of 2 has been brought about by the fact that the carrier signal had been increased and thus exerted a control on the amplifier which raised the gain of the amplifier to make a total increase in the system a factor of 2.

Thus, it becomes a purpose of my invention to provide a means for recording and reproducing sound on magnetic wire in such a manner that large variations in sound input into this system will be reproduced in the output as correspondingly large variations in the output of the recorder, without requiring that the variation in intensity of magnetization required on the

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record wire shall be excessive. Other purposes and objectives of my invention will become evident from a study of the accompanying drawings, wherein:

Figure 1 represents a block diagram of the recorder;

Figure 2 represents a block diagram of the reproducer; and

Figures 3, 4 and 5 show curves demonstrating the method of operation.

In the recorder, sound enters through microphone 1, and is finally impressed upon record wire 2 which runs perpendicularly to the plane of the drawing. Sound is recorded on this wire 2 by the action of recording coil 3 which is fed from the variable gain amplifier 4, which in turn is energized by the microphone 1. If this variable gain amplifier 4 were a standard amplifier without variable gain, the system would be a simple recording system in which the sound entering the microphone 1 would be recorded on record wire 2 by the action of recording coil 3.

However, in my system an additional signal is recorded on the record wire by the action of recording coil 5. This signal is the carrier signal generated by generator 6 and amplified through amplifier 7. It is to be observed that this carrier signal is impressed on the record wire at right angles to the other signal, but this may not be necessary if filters are employed in place of the two coils at right angles to each other. The system as described so far is satisfactory for arranging an orientation of the wire so that in the reproducer the wire would always be at right angles to the pick-up coil, as more fully described in my co-pending application Serial No. 591,675, filed May 3, 1945.

In the present invention, however, in order to apply the automatic system of volume compression, a portion of the signal from the output of variable gain amplifier 4 is rectified through rectifier 8. This signal then provides a signal at junction 9 which is proportional to the intensity of the signal being recorded on the wire through the recording coil 3.

As the signal recorded on the wire becomes greater, the output on line 9 becomes greater and this output is fed into the variable gain amplifier 4 in such a way as to reduce the gain of the amplifier 4. Thus, for example, if the input to the microphone were doubled, this system may be so arranged that the gain of the amplifier 4 is decreased by a factor of 1.41. That would mean that the output of the amplifier 4 as a result of a doubling of the input to the microphone, would only be a factor 1.41 above what it was originally. This constitutes volume compression, and consequently, the signal recorded on the wire for a given range of variation of sound intensity in the microphone covers a smaller range in recorded signal intensity on the wire. This is further shown by the graph of Figure 3, in which it will be noted that a doubling of the intensity at the microphone results in a 1.41 rise in amplitude of the magnetization current impressed on the coil 3.

In order that there may be impressed on the record wire a signal corresponding to the amount of expansion required, the output of rectifier 8 is fed through a polarity reverser 11 and into the variable gain amplifier 7. Thus, if the gain of amplifier 4 is caused to drop, the gain of amplifier 7 is caused to correspondingly rise, so that a stronger signal is recorded by recording coil 5 upon the record wire 2. Thus, when a large amount of volume compression has been used, a

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larger signal is impressed by the carrier recording coil on the record wire 2.

The record wire then carries the sound record on one axis with a certain amount of volume compression, and on the other axis it carries an orientation carrier signal which, in addition, carries a signal proportional to the amount of volume expansion needed in order to bring the audio signal back to the full range of volume.

The curve for this is shown in Figure 4, in which it will be noted that a 1.41 rise of the signal in the output of polarity reverser 11 caused by a doubling of the microphone signal output, in turn doubles the gain of the amplifier 7. Thus a doubling of the signal intensity at the microphone doubles the intensity of the signal impressed on recording coil 5.

In the reproducer 20, Figure 2, two pick-up coils 21, 22 adjacent record wire 15 are used. The audio signal to be reproduced is picked up by the pick-up coil 21, and is transmitted through amplifier 23 to the loud-speaker 24 for reproduction of the sound.

Pick-up coil 22 is responsive to the carrier signal, and the voltage picked up by this coil is amplified by amplifier 25, and passed through filter 26 and into the phase detector 27.

Similarly, the output of amplifier 23 is fed into filter 28 and into the phase detector 27. The output of this phase detector operates or controls motor 29 which is mechanically connected to rotate the pair of pick-up coils 21 and 22 in such a manner that the axis of coil 21 is always on the zero axis of the carrier signal and on the axis of maximum recorded audio signal. As stated hereinabove, this is in accordance with my previously described invention covered in co-pending application Serial Number 591,675, filed May 3, 1945.

The particular feature of the present application is the action obtained by the rectifier 31. This rectifier takes the output of filter 26 which is now only carrier signal, and rectifies it to obtain a direct gain controlling signal. This is fed into amplifier 23 and is used to control the gain of this amplifier. Thus, if the amplitude of the carrier signal picked up by coil 22 is increased, the signal fed into amplifier 23 will be larger and consequently, the gain of amplifier 23 will be larger.

In carrying out the example described above, if the signal picked up by coil 21 should increase by 1.41%, there would be a corresponding increase in the signal picked up by coil 22. This signal passes through amplifier 25, filter 26 and rectifier 31, and produces a gain control signal impressed on amplifier 23 which effects a gain of amplifier 23 to rise by a factor of 1.41. This coupled with the increase of 1.41% in the signal picked up by coil 21 causes the output of the loudspeaker to increase by a factor of 2. This result is shown graphically in Figure 5. It will be recalled that this is in accordance with the increase in signal which was put into the microphone, although the increase in level on the wire 2 has only been 1.41%.

Thus, a wide range of variation in sound intensity is carried by the record as a smaller range in sound intensity variations.

This is well illustrated in Figures 3 and 4, in which it can be seen that the doubling of the sound intensity increases the magnetization of both the sound channel and the carrier signal by only 1.41%. Similarly, an increase in sound level of one hundred-fold, would require only a ten-

fold increase in the level of both the sound channel and the carrier, since these vary as the square root of the sound intensity in this example.

An advantage of this method of recording on the carrier the expansion required, is that both the sound intensity and the carrier fluctuate in amplitude together. This minimizes interference between the two, since when one is strong the other is strong also. If one were strong and the other were weak, there would exist a definite possibility of interference between the two signals in case any part of the equipment were not performing its function perfectly. This danger is minimized by my invention due to the fact that the carrier and sound intensities fluctuate together.

It may be desirable in carrying out my invention as herein described, to displace recording coil 5 longitudinally along the wire from recording coil 3 (see Figure 1), so as to supply advance information to the rectifier 31 (Figure 2) of a change in the degree of compression introduced during the recording operation. In this manner, the response time of the rectifier 31 is taken into account so that the expansion introduced by amplifier 23 is in relative time synchronism with the compression introduced by amplifier 4.

In the above I have described my system as applied to wire recording, and have given a specific example in which compression in accordance with the square root of the signal is achieved. It will be understood, however, that my invention may be applied to other forms of recording and that other factors of compression than those given in the specific example, may be employed. It will be further understood that there are various methods of carrying out my invention, and, consequently, I prefer to be limited only by the following claims.

I claim:

1. In a wire recording system, a wire having a first recording of signals thereon, and a second recording of signals thereon, and means controlled by said second recorded signals for controlling the reproduction of said first recorded signals.

2. In a wire recording system, a wire having a first recording of signals thereon, and a second recording of signals thereon, means controlled by said second recorded signals for controlling the effective orientation of said wire, and means controlled by said second recorded signals for controlling the reproduction of said first recorded signals.

3. In a wire recording system, a wire having a first recording of signals thereon, and a second recording of signals thereon, pick-up means for reproducing said first signals, a variable gain network supplied with said first reproduced signals as input thereto, pick-up means for reproducing said second signals, and means for controlling the gain of said network by said second reproduced signals.

4. In a wire reproducing system, a wire having a first and a second signal recording, a first winding associated with the wire for reproducing the first recorded signals, an amplifier, a second winding associated with the wire for reproducing the second recorded signals, and means for controlling the gain of said amplifier in accordance with the second reproduced signals.

5. In a wire reproducing system, a wire having a first and a second signal recording, a first winding associated with the wire for reproducing the first recorded signals, an amplifier, a second wind-

ing associated with the wire for reproducing the second recorded signals, and means for controlling the gain of said amplifier in accordance with the second reproduced signals comprising a rectifier for producing rectified signals varying in accordance with the second recording, and means for controlling the gain of said amplifier by said rectified signals.

6. In a wire reproducing system, a wire having a first and a second signal recording, a first winding associated with the wire for reproducing the first recorded signals, an amplifier, a second winding associated with the wire for reproducing the second recorded signals, means for controlling the gain of said amplifier in accordance with the second reproduced signals, and means for controlling the effective orientation of said wire in accordance with the second and first signals.

7. In a signal recording system, means for producing electric signals to be recorded varying in amplitude, means including a variable gain amplifier for automatically compressing the amplitude of the signals in accordance with the signal output of said amplifier, means for recording the compressed signals, and means controlled in accordance with the signal output of said amplifier for recording the extent of compression of the signals.

8. In a signal recording system, means for producing electric signals to be recorded varying in amplitude, means including a variable gain amplifier for automatically compressing the amplitude of the signals in accordance with the signal output of said amplifier, means for recording the compressed signals, means for recording the extent of compression of the signals comprising a source of oscillations, a variable gain amplifier connected to said source, means for varying the gain of said amplifier in accordance with the extent of compression of said first-mentioned signals, and means for recording said amplified oscillations.

9. In a signal recording system, means for producing electric signals to be recorded varying in amplitude, a variable gain amplifier connected to said means, means controlled by the output of said amplifier for automatically controlling the gain of said amplifier to compress the amplitude of the signals in accordance with the signal output of said amplifier, means for recording the compressed signals, means for recording the extent of compression of the signals comprising a second source of signals, a second variable gain amplifier, means for varying the amplification factor of said second amplifier in accordance with the compression of said first-mentioned signals, and means for recording said second-mentioned signals.

10. In a signal recording system, means for producing electric signals to be recorded varying in amplitude, a wire, means for compressing the amplitude of the signals before recording, means for magnetically recording the compressed signals, and means for magnetically recording the extent of compression of the signals on said wire.

11. In a signal recording system, a wire on which signal recordings are to be made, means for producing electric signals to be recorded, varying in amplitude, an amplifier, means for impressing said signals on said amplifier, means for varying the gain of said amplifier in accordance with the amplitude of said signals, electromagnetic means connected to the output of said amplifier for recording the signal output thereof on said

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wire, and means for recording the variations in the gain of said amplifier.

12. In a signal recording system, a wire on which signal recordings are to be made, means for producing electric signals to be recorded, varying in amplitude, an amplifier, means for impressing said signals on said amplifier, means for varying the gain of said amplifier in accordance with the amplitude of said signals, electromagnetic means connected to the output of said amplifier for recording the signal output thereof on said wire, means for recording the variations in the gain of said amplifier comprising a second source of signals, a second amplifier, means for impressing said second-mentioned signals on said second amplifier, means for varying the gain of said amplifier in accordance with the variation in gain of said first amplifier, and means for recording the output signals of said second amplifier on said wire.

13. In a signal recording system, means for producing electric signals to be recorded varying in amplitude, a wire, means for compressing the amplitude of the signals before recording, means for magnetically recording the compressed signals, and means for magnetically recording the extent of compression of the signals on said wire, said last-mentioned means being displaced longitudinally from said first-mentioned recording means.

14. In a signal reproducing system in which a recording of signals which have been compressed has been made, and a second recording of the extent of compression has been made, the second recording being recorded in an advance position in respect to time of reproduction, a reproducing means, an amplifier connected to said reproducing means, and means including a rectifier controlled by the second recording for controlling the gain of said amplifier in accordance with the extent of compression, the response time of said rectifier being such that the expansion introduced by said amplifier is in relative time synchronism with the compression at the recorder.

15. In a signal recording system, means for producing electric signals varying in amplitude, a

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variable gain amplifier connected to the output of said means, a rectifier connected in the output of said variable gain amplifier, means including circuit connections from the output of said rectifier for controlling said variable gain amplifier, a source of oscillations, a second variable gain amplifier connected to said source of oscillations, circuit connections from the output of said rectifier to said second mentioned variable gain amplifier, and means for recording the signal output of said second mentioned variable gain amplifier.

16. In a signal recording system, means for producing electric signals varying in amplitude, a variable gain amplifier connected to the output of said means, a rectifier connected in the output of said variable gain amplifier, means including circuit connections from the output of said rectifier for controlling said variable gain amplifier, a source of oscillations, a second variable gain amplifier connected to said source of oscillations, circuit connections from the output of said rectifier to said second mentioned variable gain amplifier, means for recording the signal output of said second mentioned variable gain amplifier, a reproducing amplifying means, and means controlled by the recording signals from said second mentioned variable gain amplifier for controlling the gain of said amplifying means.

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